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CEREAL CROP IMPROVEMENT FOR DRY FARMING CONDITIONS[1]

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Cereal crop improvement has been going on for thousands of years and methods of improvement have advanced from primitive ways to the highly scientific breeding technique of the present day. Exacting markets, severe competition and various soil, climatic and mechanical factors make the way difficult for the plant breeder. Among the many problems he has to face, that of drought resistance is one of the most interesting.

Drought is not a new menace, but it has been so prominent in Western Canada during the past six years and the chances of its making long periodic visits in the future are so large that it is a major factor in cereal crop improvement for the western plains area. It has been shown by Barnes and Hopkins (*2*) and others that scarcity of water is the largest limiting factor in crop production under dry farming conditions on the prairies of Western Canada. It is possible to originate varieties which are more drought resistant than those now used but great care must be taken to insure that the attainment of high drought resistance is not achieved at a sacrifice of other characters equally valuable. The matter was well put by Barnes (*1*) when he referred to the fact that our native grasses will stand the most severe drought conditions, but when used as unbroken prairie in the dry areas of Saskatchewan and Alberta will support only one head of cattle on 25 to 35 acres. He went on to state that much greater hay yields are secured from cereal crops, which are relatively non-resistant to drought, than from grass.

The present paper is a report of results on the drought resistance aspect of the cereal breeding at the University Experimental Farm, Saskatoon, Saskatchewan.

WHEAT

Wheat is the most important grain crop in Western Canada and there are interesting data available on the relative importance of drought resistance in an improvement programme. Table 1 shows grain yield in bushels per acre on summer-fallow at Saskatoon for several varieties of wheat. It is noticeable that Reliance, a variety from the cross of Marquis with the very prolific winter wheat Kanred, stands out from the others by yielding much more than they did in seasons which were favorable as to precipitation and soil moisture.

[1] A paper presented before the Western Canadian Society of Agronomy at the University of Alberta, Edmonton, June 24-26, 1935.

[2] Professor of Field Husbandry.

TABLE 1.—INTERACTION OF VARIETIES WITH YEARS AS SHOWN BY GRAIN YIELDS IN THE COMPARATIVE TEST OF WHEAT VARIETIES AT SASKATOON OVER A TEN-YEAR PERIOD

Year	Yields in bushels per acre on summer-fallow					3 SE %*
	Marquis	Reliance	Reward	Garnet	Ceres	
1925	36.6	49.8	33.0	41.7	43.8	22.1
1926	38.8	52.7	41.0	40.6	40.8	13.7
1927	36.1	40.5	31.7	35.1	36.3	14.8
1928	51.0	65.0	40.3	52.5	52.6	11.1
1929	26.1	28.1	26.4	28.2	25.4	11.8
1930	42.6	42.0	40.5	42.1	41.9	9.3
1931	19.6	21.3	13.2	17.9	17.8	34.5
1932	24.1	24.7	15.2		19.6	18.6
1933	9.8	10.1	9.2		11.3	25.2
1934	19.9	20.8	19.3	20.0	20.8	14.4
10 yr. total	304.6	355.0	269.8		310.3	5.7
Above Marquis	0.0	50.4	−34.8		5.7	
25–29 total	188.6	236.1	172.4	198.1	198.9	7.1
30–34 total	116.0	118.9	97.4		111.4	8.9
Difference	72.6	117.2	75.0		87.5	

*The significance of a difference between two yields is found by multiplying the average of the two yields by the percentage number in the column headed "3 SE %" and comparing the value obtained with the difference between the two yields. If the difference is the larger number, it is considered that the variety with the higher yield is significantly better yielding. For example: To obtain the significance of the difference between the 10 year total for Marquis and Reliance, multiply 329.8 (the average of 304.6 and 355.0) by .057 (5.7%) which gives 18.8 bushels. As the difference, 50.4 bushels, is much larger than 18.8 bushels, the odds are very great that Reliance is the better yielder.

The acre yield of Reliance for the ten-year period was 355 bushels, which was 50.4 bushels more than the Marquis total, 84.8 bushels more than the total for Reward, and 44.7 bushels more than the Ceres total. These totals are made up of two parts, that for the first five year period and that for the second five years. In the first period, Reliance yielded 47.5 bushels more than Marquis and in the second period, only 2.9 bushels more. That is, Reliance outclassed Marquis greatly in the favorable years and held its own against Marquis during the drought years.[3] Since Marquis was able, during the drought years, to ap-

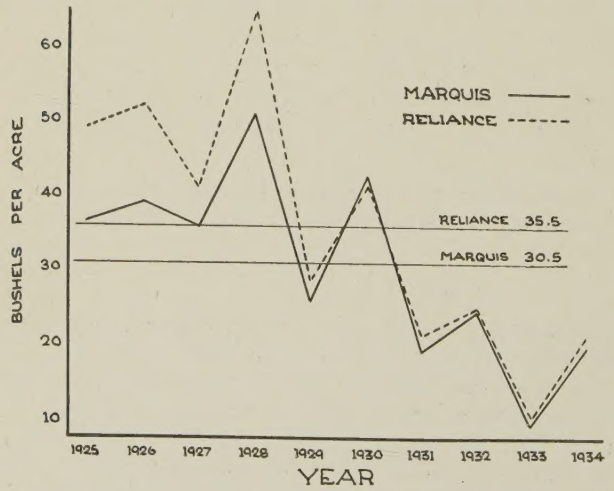

FIGURE 1. Comparative yields of Marquis and Reliance showing the large superiority of Reliance in the favorable seasons of 1925 to 1928

[3] The 1935 results have come to hand just as this paper goes to the press. They are of particular interest as 1935 was a favorable season such as those of the first five year period. The yields are as follows: Reliance 39.5 bushels per acre, Ceres 37.0, Marquis 34.5, Garnet 33.8 and Reward 32.1.

proach more closely its ten year average yield than was Reliance, it might be said that Marquis is the more drought resistant of the two. Yet the fact remains that Reliance produced a total of fifty bushels more than Marquis. The performance of Ceres and Reward resembled that of Marquis as far as comparative yields during the two periods of years are concerned. The Marquis and Reliance results are shown graphically in Figure 1. Statistical analysis of the data by Fisher's (*3*) variance method showed that the interaction of varieties with season is highly significant, that is, the varieties differed distinctly from each other in their reaction to favorable and unfavorable years.

Table 2 gives the grain yields of four wheat varieties on spring-plowed stubble for the period 1930 to 1934. The comparative positions of the

Table 2.—Grain yield of wheat varieties grown on spring plowed stubble at Saskatoon over the four year period 1930 to 1934

Year	Yields in bushels per acre				3 SE %*
	Marquis	Reliance	Reward	Ceres	
1930	40.6	43.3	36.6	45.4	18.7
1931	4.0	3.8	2.0	4.2	18.9
1932	18.9	20.7	18.8	17.2	9.2
1934	4.1	3.8	4.9	4.6	17.9
4 yr. total	67.6	71.6	62.3	71.4	6.7

*See note at bottom of Table 1.

varieties are the same as in the summer-fallow results of Table 1 for the same period, excepting that Ceres did relatively better than the others on plowing. It is of interest that Reliance had a slightly larger lead over Marquis than on fallow for the same period.

Table 3 shows yield results for two selections made from Marquis compared with results on Marquis and Reliance. The reaction of these

Table 3.—Interaction of varieties with years as shown by the grain yields of two Marquis selections in comparison with Marquis over an eight-year period at Saskatoon

Years	Yields in bushels per acre on summer-fallow				3 SE %*
	Marquis	Reliance	S.A.C. 151	S.A.C. 146	
1927	36.1	40.5	52.2	49.6	12.5
1928	51.0	65.0	57.9	61.6	5.0
1929	26.1	28.1	31.9	29.1	12.0
1930	42.6	42.0	42.5	40.9	8.2
1931	19.6	21.3	18.7	17.9	30.1
1932	24.1	24.7	23.9	22.8	14.6
1933	9.8	10.1	10.5	11.2	21.5
1934	19.9	20.8	18.1	20.4	13.1
8 yr. total	229.2	252.5	255.7	253.5	5.8
Above Marquis	0.0	23.3	26.5	24.3	
27–29 total	113.2	133.6	142.0	140.3	6.1
30–34 total	116.0	118.9	113.7	113.2	7.8
Difference	−2.8	14.7	28.3	27.1	

*See footnote of Table 1.

two selections, S.A.C. 146 and S.A.C. 151, is very similar to that of Reliance in that they outclassed Marquis considerably in the favorable seasons but were no better than Marquis in the dry years. In fact, their total yields for the years 1927 to 1929 excel those of Marquis by 27.1 and 28.8 bushels, respectively. Yet in the dry period 1930 to 1934, both selections yielded slightly less than Marquis.

OATS

Oats are particularly sensitive to drought conditions yet are relied upon to a large extent as a source of feed in the dry areas of Western Canada. It is, therefore, highly desirable to have varieties which will do reasonably well in dry seasons and perform satisfactorily under moist conditions. To the oat plant, drought is bad, but extreme heat is also bad and the combination is worse. On the whole common oats, *Avena sativa*, thrive much better in the relatively cool climate of Canada than in the central agricultural area of the United States and it seemed to the writer that oat varieties bred to resist the hot, dry summer weather of Ohio might be useful in our Canadian drought resistant program. Accordingly, in 1931 we secured, through the courtesy of the Ohio Experiment Station, several hybrid lines and tested them against Gopher, Banner and other standard sorts. An observation test was run in 1932, and in 1933 and 1934 twenty of the lines were given a replicated plot test. The results on five of the most promising lines are given in Table 4.

TABLE 4.—COMPARATIVE PERFORMANCE OF BANNER, GOPHER AND FIVE OAT HYBRIDS WHEN GROWN ON SPRING PLOWED STUBBLE IN 1933 AND ON SUMMER-FALLOW IN 1934 AT SASKATOON

—	Years	Gopher	Hyb. 117	Hyb. 121	Hyb. 123	Hyb. 132	Hyb. 137	Banner
Total plant yield in tons per acre	1933	.32	.35	.37	.38	.46	.33	.30
	1934	1.04	1.04	1.00	1.15	1.08	1.04	1.11
Grain yield in bushels per acre	1934	35.3	38.8	38.0	44.1	41.3	38.3	38.8
Height in cm.	1933	24	28	28	30	36	28	27
	1934	79	85	82	84	87	82	84
Days maturing	1933	76	66	71	66	66	66	83
	1934	86	83	83	84	84	84	91
Plumpness in per cent	1933	70	65	65	65	65	65	65
	1934	78	69	67	70	68	67	86

These results show that the Ohio hybrids stood up remarkably well under drought conditions at Saskatoon. The five hybrids produced more feed than either Gopher or Banner in 1933, and two of them outclassed Gopher in feed yield on summer-fallow in 1934. No grain yields were obtained in 1933, but in 1934 all of the hybrids outyielded Gopher and one of them beat Banner. One of the most interesting features of the hybrids was their length of straw under dry conditions. They excelled Gopher in both years, and Banner in 1933. In earliness, they were outstanding, being from 5 to 10 days earlier than Gopher and 12 to 17 days earlier than Banner in 1933. In 1934 they were 2 to 3 days earlier than Gopher.

Plumpness of kernel is also a valuable character and it is here the hybrids fell down, for, although they equalled Banner in 1933, they were considerably less plump than both Banner and Gopher on summer-fallow in 1934. It is apparent that the hybrids suffered less than Gopher and Banner from the drought conditions of 1933 and that they were at a disadvantage with respect to grain plumpness under the more favorable conditions in 1934. Extensive reselection work is now in progress as there seems to be a fair prospect of obtaining valuable material from these hybrids, either directly by selection or indirectly by crossing.

BARLEY

At Saskatoon, the comparative rod row test of standard barley varieties reveals important differences in reaction to drought conditions. Table 5 contains yields of a number of the leading barley varieties as grown on summer-fallow at Saskatoon during the nine years 1926 to 1934.

TABLE 5.—INTERACTION OF VARIETIES WITH YEARS AS SHOWN BY GRAIN YIELDS IN THE COMPARATIVE TEST OF BARLEY VARIETIES AT SASKATOON OVER A NINE YEAR PERIOD

Year	Yields in bushels per acre on summer-fallow					3 SE % *
	Trebi	Hannchen	Regal	Colsess	O.A.C. 21	
1926	67.2	54.8	44.2	51.0	47.3	22.0
1927	91.9	77.9	64.9	79.8	63.3	12.5
1928	115.4	81.3	107.8	89.7	85.0	23.7
1929	42.6	44.9	44.0	36.0	27.9	16.3
1930	68.2	54.2	70.8	61.9	57.3	13.2
1931	49.8	46.4	42.2	36.9		19.6
1932	52.8	52.5	47.5	47.0		8.4
1933	22.8	25.2	25.0	23.2		18.8
1934	46.6	44.8	48.2	45.6	39.0	8.3
9 yr. total	557.3	482.0	494.6	471.1	319.8	5.8
Above Hannchen	75.3	0.0	12.6	−10.9	−62.2	
Total 26, 27, 28, 30	342.7	268.2	287.7	282.4	252.9	9.3
Total 29, 31, 32, 33, 34	214.6	213.8	206.9	188.7		6.8
Difference	128.1	54.4	80.8	93.7		

*See footnote of Table 1.

The Trebi and Hannchen results show a variety versus year interaction resembling closely that which was brought out by the Reliance and Marquis results. Trebi yielded much higher than Hannchen in the favorable seasons but in the dry seasons, kept close to Hannchen. Hannchen is considered highly on account of its drought resisting qualities but Trebi possesses such high capacity to yield that it equalled Hannchen in the five drought years and excelled it to the extent of 74.5 bushels during the favorable seasons 1926, 1927, 1928 and 1930. The difference in the reaction of the two varieties during the two periods of years is very highly significant. The other varieties showed less striking responses to seasonal differences. Regal more or less resembled Hannchen in yielding capacity. Colsess resembled Regal and Hannchen during the favorable period but suffered more during the dry years. O.A.C. 21 showed a particularly poor response during the two dry years it was in the test. Graphical representation of the data is given in Figure 2.

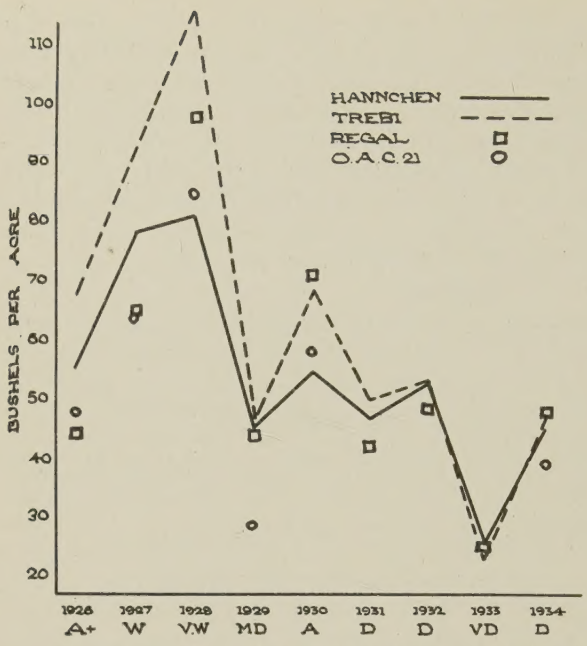

FIGURE 2. Comparative yields of four barley varieties on summer-fallow at Saskatoon, showing the large superiority of Trebi over Hannchen during the favorable seasons of 1926, 1927, 1928 and 1930. (*A* = average season, *W* = wet season, D = dry season, *V* = very and *M* = medium.)

The results of standard barley varieties on spring plowed stubble for the five years the test has been carried are given in Table 6. Hannchen averaged higher in yield than any of the other varieties largely owing to its greater success in the seasons of 1931 and 1934 when the soil moisture reserve was unusually low. Probably there would have been similar results in 1933 but the drought was so severe the barley on spring plowing failed for the most part to develop heads and no grain yields were obtained.

TABLE 6.—GRAIN YIELD OF BARLEY VARIETIES GROWN ON SPRING PLOWED STUBBLE AT SASKATOON OVER THE FOUR YEAR PERIOD 1930 TO 1934†

Year	Yield in bushels per acre				3 SE %*
	Hannchen	Trebi	Regal	Colsess	
1930	57.9	56.4	53.3	59.0	19.9
1931	20.8	15.3	13.4	15.5	19.6
1932	43.2	42.1	42.0	40.4	10.9
1934	4.6	2.2	1.8	1.6	39.9
4 yr. total	126.5	116.0	110.5	116.5	14.4

*See footnote of Table 1.
†No grain yields obtained in 1933 owing to severe drought.

NEW CROSSES

In the cereal breeding work at the University of Saskatchewan, drought resistance has been stressed for the past four years. Ability to produce a reasonable length of straw, a reasonably well developed inflorescence and a reasonably plump kernel were the principal criteria used in selecting for drought resistance. Each hybrid plant was examined according to these standards. It is felt that the lines retained after the four years of selection are satisfactorily drought resistant. If the next year or two are favorable seasons, it will then be possible to pick from among these drought resisting hybrids, those which are able to respond copiously to the favorable conditions, and yet be otherwise desirable.

DISCUSSION

The plant breeder of the open plains of Western Canada necessarily regards drought resistance as one of the important characters in his breeding programme. The breeder's almost continuous selection for drought resistance is aided by Nature, and results in the early elimination of most of the varieties which are poor in drought resistance. Among the remaining varieties some are more drought resisting than others or at least are able to maintain a closer approach to their long time average yield during dry years than do the other varieties. Marquis is an example of such a variety.

Whether or not Marquis is really more drought resistant than Reliance, Selection 151 and Selection 146, the fact remains that these varieties produced more bushels per acre than Marquis over a long period of years but were not particularly outstanding during a period of five dry years. All other things being equal, the farmer of Western Canada wants the variety which gives him the greatest net return. Since the size of the crop in any particular district of Western Canada has practically no relationship to the market price of wheat, a variety which will produce ten bushels per acre in a dry year and forty bushels per acre in a good year is more valuable than one which will produce eleven bushels per acre in the dry year and thirty in a favorable season. The plant breeder must keep this point constantly in mind as there is a great temptation during a series of dry years to pay much attention to differences in yield and discard hybrid lines and selections which do not equal Marquis in this respect, although they are satisfactory otherwise. It might well be that many of these lines would outclass Marquis if tested over a longer period of years.

In the barley results the Trebi versus Hannchen barley comparison is very similar to that of Marquis wheat versus Reliance and the two new selections.

In the oat examples used it is clear that varieties possessing outstanding drought resistance are available, but the question to be answered there is whether or not those varieties will be best over a long period of years.

If an agricultural area were consistently so dry that only the most drought resistant varieties of the adapted crops could be grown with any satisfaction, it is obvious that under dry farming practices, those varieties would have to be grown. But when a large fertile plains area has large variations in annual precipitation with series of favorable and unfavorable years, then it is not obvious that the most drought resistant varieties are the best to use. In fact, it is the favorable years that make it possible to carry on through the unfavorable ones; consequently the behavior of crops and varieties of these crops during favorable years is a vital matter. The best crop and the best varieties are those which produce the most satisfactory results over a long period of years.

SUMMARY

1. A study of the suitability of different wheat and barley varieties to open plains conditions was made, using grain yields obtained over a period of years.

2. During a ten-year period consisting of five favorable years followed by five dry years, Reliance wheat yielded 47.5 bushels more than Marquis

during the first period but only 2.9 bushels more than Marquis in the dry period. The interaction between varieties and years was highly significant statistically.

3. A similar analysis of data from Marquis and two selections from Marquis showed an even more striking interaction between varieties and years. The selections yielded 27.1 and 28.8 bushels, respectively, more than Marquis in the favorable years and 2.8 and 2.3 bushels less than Marquis in the dry years.

4. Barley variety results were equally striking. Trebi yielded 74.4 bushels more than Hannchen in a series of favorable years and only 0.8 bushels more than Hannchen in the dry years. The variety-year interaction was highly significant.

5. Results on some new oat introductions show that they possess a high degree of drought resistance, but they have not yet been tested in wet years, and the wheat and barley results point to the necessity of having a long time average before drawing conclusions as to the suitability of a variety for the dry plains region.

6. The study demonstrates that even a period of five years might be quite inadequate for revealing a variety's usefulness, and that the period of test should be long enough to include both favorable and unfavorable years.

REFERENCES

1. Barnes, S. Economic aspects of drought resistance. Sci. Agric. *12* : (4) 206-208. 1931.
2. Barnes, S. and Hopkins, E. S. Soil moisture and crop production. Dom. Dept. Agric. Bul. 130 N.S. 1930.
3. Fisher, R. A. Statistical methods for research workers. Oliver and Boyd. London. 383 pp. 1930.

Résumé

Amélioration des céréales dans les conditions de culture en terre sèche. J. B. Harrington, Université de la Saskatchewan, Saskatoon, Sask.

Il a été fait une étude de l'adaptation de différentes variétés de blé et d'orge aux conditions des plaines nues, basée sur les rendements de grain obtenus pendant un certain nombre d'années. Au cours d'une série de dix années, dont les cinq premières avaient été favorables et les cinq autres sèches, le blé Reliance a produit 47.5 boisseaux de plus que le Marquis pendant la première période mais seulement 2.9 boisseaux de plus pendant la période sèche. Cette différence entre les variétés et les années est des plus significatives au point de vue statistique. Une analyse semblable de données recueillies sur le Marquis et deux sélections du Marquis accusait une différence encore plus frappante entre les variétés et les années. Les sélections ont rapporté 27.1 et 28.8 boisseaux respectivement de plus que le Marquis dans les années favorables et 2.8 et 2.3 boisseaux de moins dans les années sèches. Les résultats donnés par les variétés d'orge sont également frappants. La Trébi a rapporté 74.4 boisseaux de plus que la Hannchen dans la série d'années favorables et seulement 0.8 boisseau de plus dans les années sèches. La différence est ici des plus significatives. Les notes prises sur quelques nouvelles introductions d'avoine montrent qu'elles possèdent un haut degré de résistance à la sécheresse, mais elles n'ont pas encore été éprouvées dans les années humides, et les résultats donnés par le blé et l'orge montrent qu'il est nécessaire d'avoir une moyenne à long terme avant de tirer des conclusions sur l'adaptation d'une variété pour la région des plaines sèches. L'étude démontre que même une période de cinq années pourrait être tout à fait insuffisante pour révéler l'utilité d'une variété et que la période d'essai devrait être assez longue pour comprendre à la fois les années favorables et les années défavorables.

CULTURAL AND ROTATIONAL PRACTICES FOR DRY LAND AGRICULTURE[1]

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CROP ROTATIONS

One very essential feature of any successful rotation is that it contains a large percentage of the acreage devoted to the most profitable crops. It is obvious that neglect to observe this requirement would very quickly result in financial failure.

The type of farming which is followed will influence the selection of the crops to be used in the rotation. Thus live stock or mixed farming will require a larger acreage of hay, pasture, corn or other forage crop than will straight grain farming. The amount of the live stock will influence the amount of these forage crops which it will be necessary to grow.

However, it would seem wise, before deciding upon the type of farming to follow, to determine what yields of the various crops might normally be expected in various parts of the prairie. The Dominion Experimental Farms have conducted experiments on crop rotations over a fairly long period of years and a study of the yields secured from different types of crops on the various farms may be of some interest. The yield data available for crops grown in Western Canada are not absolutely comparable among the various farms because the comparisons are not for the same period of years. Even where this is the case the comparisons may not be absolutely fair inasmuch as during the last four years, for example, some regions such as Southern Saskatchewan and Southwestern Manitoba, have had very severe crop failures, while the northern crop districts have enjoyed average or even above average yields. Only a very long average would overcome these weaknesses. However, notwithstanding any imperfections, a study of these yields throws some light on the reason why some crops are preferred over others.

Prices for different products will undoubtedly also affect the selection of certain crops. If wheat is high in price and live stock products low the tendency will be towards wheat, while if the reverse be the case the tendency will be to grow more fodder crops for live stock.

WHEAT YIELDS ON SUMMER-FALLOW AND STUBBLE LAND

Table 1 shows the yields of wheat on summer-fallow and on stubble land on several farms in the Prairie Provinces. The periods of year during which the yields have been averaged is not the same for all the stations but the period in all cases is long enough to supply some very useful information.

Table 1.—Wheat yields in bushels per acre

Station	No. of years	Summer-fallowed land	Stubble land
Morden	11	27.7	24.4
Brandon	8	30.3	20.3
Indian Head	22	26.8	16.9
Rosthern	10	28.2	20.5
Scott	22	18.5	17.0
Swift Current	10	19.0	10.4
Lethbridge	22	25.7	18.4
Lacombe	20	29.7	18.5

[1] Paper presented before a joint session of the Western Canadian Society of Agronomy, the soils group and the agricultural engineering group of the C.S.T.A. at the University of Alberta, Edmonton, June 26, 1935.

[2] Dominion Field Husbandman.

It is apparent that at most of the stations the yields of wheat on summer-fallow are quite satisfactory. At some stations infestations of weeds have reduced yields, particularly on stubble wheat, and in one case even on what seemed to be well worked summer-fallow.

FREQUENCY OF SUMMER-FALLOWING IN ROTATIONS

The most extensively used crops rotation in the Prairie Provinces is the three-year rotation of summer-fallow, grain and grain. It is probable that in the drier portions of the prairie the two-year rotation of summer-fallow and grain would be preferable. In dry years the second crop of grain after fallow is too light to be worth harvesting. As will be seen by referring to the wheat yields at Swift Current almost as much wheat will be secured from the two- as the three-year rotation with some very decided advantages.

In the first place, the crop is much cheaper to handle, being smaller in acreage, while second, it may be seeded earlier in the spring ensuring greater freedom from rust and frost. A third advantage arises from greater freedom from weeds which may be enjoyed on alternate grain and summer-fallow.

Even in the more humid areas of the prairie, the summer-fallow should not be eliminated. In such regions the land should be fallowed once every four to six years.

RELATIVE YIELDS OF HAY CROPS AT DIFFERENT STATIONS

When travelling across Canada it is striking to observe the relatively large acreage of hay and pasture crops in Eastern Canada and the relatively small acreage of these crops in the Prairie Provinces. Within the Prairie Provinces themselves, there is quite a wide range of variation especially in the adaptability of hay crops, if not in the actual acreage cropped.

TABLE 2.—HAY YIELDS IN TONS PER ACRE

Station	No. of years	Yield per acre (tons)
Morden	6	2.83
Brandon	8	2.00
Indian Head	12	1.38
Rosthern	10	.81
Scott	8	.86
Swift Current		.41
Lethbridge	Too poor to grow	
Lacombe	9	1.34

Table 2 gives the yields of hay crops grown in rotations on the various Dominion Experimental Farms. The period of years included in the average are not always of the same length or the same years, but they embrace sufficient time to give some idea of what may be expected. The same hay mixtures are not used in all cases but whatever mixture has been used has been thought to be the most productive for that particular farm.

The largest yields of hay, it will be seen from the above table, have been secured at Morden, Manitoba, where the moisture conditions have been most favourable. It is probable that these yields should be reduced somewhat if the last year or two of drought and grasshopper damage were included.

The yields of hay become lower as drier conditions are experienced until at Lethbridge and at Swift Current the hay and legume crops are too unproductive to include in rotations. Oat hay, however, at Lethbridge, gave a yield of 2.15 tons per acre which would probably be five times what could be secured from grass or legumes.

It is obvious that before including grass or legumes in a rotation, it is desirable to know approximately what yield might be expected. In the dry regions the yields of these crops have not been sufficiently high to be profitable.

RELATIVE YIELDS OF CORN AT DIFFERENT STATIONS

The corn crop is primarily adapted to regions of ample precipitation and especially to a warm temperature. Most parts of the Prairie Provinces are not particularly suitable, therefore, for the production of large yields of corn.

Occasionally waves of enthusiasm sweep over the country in favor of certain crops, something akin to the enthusiasm for certain economic doctrines. The records from experiments conducted over a long period of years are very useful in deciding whether much or little weight should be given to the claims in favor of certain crops.

In both the dry and cool regions of the prairie, corn has not been a satisfactory crop. The yield of dry matter or of total digestible nutrients would not be comparable in these areas with what could be secured from oat hay.

Table 3.—Corn yields in tons per acre

Station	No. of years	Yields per acre (tons)
Morden	11	8.41
Brandon	8	6.22
Indian Head	12	6.66
Rosthern		4.11
Scott	Too poor to grow	
Swift Current	10	2.93
Lethbridge	18	4.33
Lacombe	13	8.38

The corn crop, it is true, is a very favourable crop to precede grain but in dry years it withdraws so much moisture that the yield of the following crop is greatly reduced. Corn has some but not a great deal of value in checking drifting. It costs something additional to produce as compared with bare summer-fallow, and unless carefully cultivated may promote weed growth.

The yield of corn which is reported for Lacombe seems somewhat higher than might be expected for that part of the country. The explanation may rest in the fact that the soil is somewhat light and sandy at Lacombe, which is favourable for corn.

CULTURAL METHODS—SUMMER-FALLOW TREATMENT

With approximately 13,000,000 acres of land in summer-fallow in 1932 in the three Prairie Provinces, it is obviously a matter of considerable importance to learn the best method of summer-fallowing. Out of a total of 55,000,000 acres under cultivation 13,000,000 acres were in summer-fallow or nearly one-quarter of the acreage. In the drier parts of the prairie the percentage of land in fallow is greater, reaching about 50%,

while in the more humid regions a smaller percentage is included. In very few, if any places, however, should the summer-fallow be completely excluded.

The problem arises, therefore, as to what are the best methods of summer-fallowing under various soil and climatic conditions. In fact not only do soil and climatic conditions exert an influence, but the kind and amount of various weeds in the land also affects the method of summer-fallowing. Indeed, this factor is perhaps the most important of all.

The best method of summer-fallowing land, it may be said, is the method which will conserve moisture control or eradicate weeds and prevent soil drifting. These are the objects of the summer-fallow. How may they be achieved?

The Dominion Experimental Farms have conducted a large number of experiments on methods of summer-fallowing. A few important points may be mentioned.

Early working of the summer-fallow is decidedly advantageous. This keeps weeds in check and thereby conserves more moisture. What method is used to eradicate the weeds is immaterial, whether it be plow, cultivator or disc. It is important to prevent weeds making too great a growth.

The plowless summer-fallow is a relatively new method of handling the land. It gives results fully equal to the plowed fallow under most conditions and in some circumstances it has some decided advantages. It enables all the land to be worked more quickly thereby preventing weeds growing too large on a portion of the farm. It leaves the stubble and other trash on the surface of the ground, thereby assisting in the control of soil drifting. The weed seeds are not buried too deeply, thereby facilitating their germination and subsequent eradication to a greater extent than would be the case if the land were plowed.

One interesting feature of recent summer-fallow methods is the success which seems to follow a relatively few treatments or cultivations of the land. In the drier regions three cultivations and sometimes two seem to be sufficient. Even in the more humid parts of the country four or five cultivations or discings are sufficient. This treatment would be adequate for annual weeds but, of course, would be inadequate for perennials. Obviously, this method of handling summer-fallow is much cheaper than the old standard method of summer-fallowing which consisted of plowing in June and cultivating thereafter as required, often more frequently than was really necessary.

Attempts have been made to improve the summer-fallow by plowing under such green manure crops as peas, tares and buckwheat. The attempts were a failure, as the yields from these plots were less than from bare fallow. These experiments were conducted on our stations at Brandon, Indian Head, Scott and Lacombe, on the prairie. They have not been conducted on the northern grey forest soils which are extremely poor.

Apparently the moisture used by these crops has more than compensated for the benefit they are supposed to afford. It may be said in this connection, however, that even in Eastern Canada, where moisture conditions are much more favourable than in the West, green manure crops have not been successful.

SUMMER-FALLOW SUBSTITUTES

Many methods have been tried in an effort to replace the summer-fallow. Intertilled crops have been grown, such as corn, sunflowers and potatoes. Grain has been seeded in rows of two or three drills and intertilled. Oats have been used for green feed. In the more humid areas, the land in hay and especially in legume hay, has been plowed early after the first cutting has been harvested and cultivated during the remainder of the year to provide a partial summer-fallow.

The need for a summer-fallow substitute is probably greater for farmers having a small acreage, such as a one-quarter or one-half section farm. Some of these farmers have sufficient labour and equipment to handle a larger acreage and desire, therefore, to crop a larger percentage of their own land.

The results of experiment have always shown the summer-fallow to be superior to any summer-fallow substitute. In the dry regions the results have been much worse than in the more humid areas.

The most efficient summer-fallow substitutes have been potatoes followed by corn. As it is not possible to grow a very extensive area of potatoes, this crop is not of very much value. The yields of corn have not been very satisfactory in the dry regions.

Grain crops grown in two or three drills and intertilled have given results somewhat poorer than corn. Oats for green feed have given decidedly the poorest results of any of the summer-fallow substitutes. The greatest weakness of the summer-fallow substitute system is the trouble with weeds. Weeds cannot be controlled sufficiently in any system of intertillage unless some hand hoeing is done. This is particularly the case with grain in rows where the land between the two or three drills cannot be reached by cultivating machinery. If hand labour were available to hoe the weeds this system would be fairly satisfactory in the more humid parts of the prairie.

The partial summer-fallow after a legume hay is very good in the more humid regions. It is worthless in the dry regions.

STUBBLE TREATMENT

With approximately 26,000,000 acres of land in the three prairie provinces seeded on stubble land, it is important to learn the best methods of handling this land for grain crops. Stubble land is frequently without much, if any, reserve of soil moisture. It is often polluted with weed growth. It is not in immediate condition for rapid seeding. Accordingly, methods of preparation must be used which will give the best results under the circumstances.

In the more humid parts of the prairie it is possible to fall plow stubble land but in the dry regions this practice is most inadvisable. Spring plowing in these areas gives much superior results.

Burning the stubble gives excellent results from the point of view of the yield obtained but it is very conducive to soil drifting. Wherever there is any possibility of drifting taking place, or of gradually creating conditions which in later years might develop into a condition where this might occur, the stubble should not be burned. Where burning is practised

it is advisable to cultivate or give some treatment to the land before seeding.

Handling the land without plowing by means of the disc harrow, cultivator or one-way disc, gives yields about equal to those obtained from spring plowing. It is a more rapid method and facilitates earlier seeding. It is not as efficient, perhaps, as plowing insofar as weed control is concerned, especially under certain conditions, but it is more efficient under other systems. However, surface working of the land leaves the stubble on the surface and helps to control soil drifting.

With some weeds, such as wild oats, it has been learned on the Dominion Experimental Farms, that our former standard method of handling the land in a three-year rotation of summer-fallow, wheat and wheat is absolutely ineffective. This standard method has been to plow the summer-fallow in the middle of June and cultivate during the remainder of the season as required. For the second crop of wheat the stubble has been fall or spring plowed. Wild oats have become so bad on at least three of our experimental farms that it has been necessary in several years to cut the second crop for green feed before the wild oats ripened.

Several methods have been learned for controlling wild oats. Where grass or legume hay crops are used in the rotation this is very successful. Where barley is used or oat green feed is grown, these are very helpful. However, where it was desired to continue with a three-year wheat rotation, other methods had to be used. A two-year wheat and summer-fallow rotation has been very useful.

The plowless method of handling both the summer-fallow and the stubble land has been very successful in checking wild oats. This method keeps the seeds near the surface where they germinate and thereby allow the weed plants to be destroyed by cultivation. Deferred seeding of the second grain crop until one growth of wild oats may be destroyed is very helpful.

New types of combination tillage and seeding implements have been recently placed on the market. These machines have some advantages and some disadvantages, which should be considered for the special circumstances in which they are to be used.

THE REACTION OF WHEAT VARIETIES TO DIFFERENT DATES OF SOWING[1]

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INTRODUCTION

In Western Canada a farmer usually commences sowing wheat between April 15th and May 1st, and sometimes the operation is not completed until the first of June. Many valuable experiments have been conducted to determine the best time to sow different crops and a considerable amount of information has been obtained. But experiments on the best time to sow different varieties within the same species, such as common wheat, are rare.

It has been observed frequently that different varieties of wheat do not maintain the same relationships year after year as to yield, height and so on. The environmental conditions present in a given season may favor one variety and the conditions the next year may favor another. Sowing at different dates also gives different environments. Wheat sown April 20th meets the day to day weather of the season in altogether different stages of development than when sown May 20th. Wheat of the two sowings germinates and passes through critical growth stages under different temperature, moisture and light conditions.

Each of the leading varieties of wheat in Western Canada occupies millions of acres of land, and sowing at different dates is widely practiced without particular regard to differences in varietal response. It would appear to be highly important to find out how each of these varieties reacts to various environmental conditions. A study was made, therefore, for the purpose of ascertaining the extent to which varieties might differ in response to different environments as furnished by different dates of sowing. The present paper is a report on this study and will be limited to two characters, viz.: grain yield and plant height.

PROCEDURE

The experiment was planned by the senior writer in 1930 and carried in a preliminary manner in 1931 with four varieties replicated six times at each of nine weekly dates. In 1932 it was conducted with five varieties in the form of a Latin Square and with nine dates as in the previous year. In 1933, financial stringency necessitated the reduction of the project to two varieties which were replicated six times in a randomized manner at each of nine dates. The study was continued on the same basis in 1934. The taking and compiling of data was done by several persons in 1931 1932 and 1933 and by the junior writer in 1934.

Standard stocks were used of the various Marquis (Sask. 100), Reward (Sask. 1003), Ceres (Sask. 1212) and Garnet (Sask. 791).[4]

Triple rod row plots one foor apart with the centre row used for yield and height data were used each year. The experiment was on spring plowing in 1931 and on summer-fallow from 1932 to 1934.

[1] Paper presented before the Western Canadian Society of Agronomy at the University of Alberta, Edmonton, Alberta, June 24-26, 1935.
[2] Professor of Field Husbandry.
[3] Graduate Student Assistant.
[4] The Canadian Accession Numbers of these stocks are 1691, 1509, 1263 and 1316, respectively.

The data were analysed by using Fisher's Variance Method. In this study, it is not a question of whether one date outyielded another or whether Marquis proved to be the higher yielding wheat, but rather, whether Marquis outyielded Reward at one date of sowing more than at another, or, on the other hand, differed from Reward by an almost constant amount throughout the series of dates. This information is shown in the variance analysis as the interaction between dates and varieties. A statistically significant interaction indicates that the varieties responded differently to the various environments to which they were subjected. The significance of the different responses of the two varieties was also measured by comparing the calculated Standard Error of a Difference with the difference between the varietal differences at any two dates. By this method a more detailed examination of the reaction of the two varieties was possible.

GRAIN YIELD

1931 Results

In 1931 the varieties used were Marquis and Ceres, two fairly early maturing varieties, and Reward and Garnet, two very early ones. This was a dry year as the previous fall had been dry and no appreciable rain fell until June 29th with very little afterwards. In addition to this, the test was conducted on plowed stubble so that the varieties withstood very dry conditions. The extreme drouth in the early part of the season and a heavy rain towards the latter part of June probably accounts for the fact that the varieties did not attain their best yield until the May 18th sowing and explains the extremely low yield of the two early varieties for the first two dates. The results are presented in Table 1.

TABLE 1.—GRAIN YIELDS IN BUSHELS PER ACRE OF FOUR LEADING WHEAT VARIETIES FROM NINE DATES OF SOWING AT SASKATOON IN 1931. EACH YIELD IS THE AVERAGE OF SIX .00038-ACRE PLOTS ON SPRING-PLOWED STUBBLE

Variety	Date of Sowing								
	April 21	April 27	May 5	May 12	May 19	May 26	June 1	June 9	June 15
Marquis	9.0	17.2	17.3	16.2	20.6	18.6	16.1	12.1	9.6
Reward	3.9	5.4	11.8	10.2	15.3	16.5	12.2	13.7	9.1
Ceres	8.4	11.5	14.3	13.2	19.0	19.7	18.7	16.1	11.1
Garnet	5.3	5.5	10.1	12.4	15.1	16.2	14.8	17.9	9.8

Standard error of mean yield of a variety = 6.1%.

Considering the comparative yields of the varieties at the different dates of sowing it is apparent that Marquis and Ceres yielded much better than Reward and Garnet when sown early but were equalled or excelled by them when sown late. This behavior constitutes a definite interaction between varieties and dates of sowing, that is to say, the yield relationships of the varieties for some dates of sowing were different than for other dates of sowing. The variance analysis shows this interaction to be highly significant. There was also a significant interaction between Marquis and Ceres. When sown late, Ceres yielded more than Marquis but in the early sowings was outyielded by Marquis. Significant interactions of

varieties and dates were also obtained with respect to the following pairs of varieties: Garnet-Ceres, Reward-Marquis, and Garnet-Reward. It is interesting to note that in the four later dates Ceres was the best of the four varieties.

1932 Results

The same four varieties were used in the 1932 test. In this year, moisture conditions were quite favorable. Rains in April and May gave early sown grains a good start and the three inches of precipitation which fell in June enabled them to produce high yields. The varieties all produced their best yields when sown early. The results are given in Table 2.

TABLE 2.—GRAIN YIELDS IN BUSHELS PER ACRE OF FOUR LEADING WHEAT VARIETIES FROM NINE DATES OF SOWING AT SASKATOON IN 1932. EACH YIELD IS THE AVERAGE OF FIVE .00038-ACRE PLOTS ON SUMMER-FALLOW

Variety	Date of sowing								
	April 5	April 26	May 2	May 7	May 14	May 21	May 28	June 4	June 11
Marquis	34.6	33.9	33.6	29.5	26.6	24.4	18.0	16.6	17.6
Reward	29.4	29.2	28.6	24.6	23.2	23.1	20.2	18.3	19.9
Ceres	33.0	34.0	33.9	27.9	26.3	25.2	20.3	18.9	17.0
Garnet	31.9	32.9	30.8	28.0	26.2	24.6	21.5	21.4	18.3

Standard error of mean yield of a variety = 3.1%.

There was a significant interaction between varieties and dates as in 1931. Reward and Garnet again surpassed Marquis and Ceres in the late dates, though considerably outyielded by them in the early ones.

1933 Results

The following year, 1933, was extremely dry. A dry fall preceding a summer in which the heaviest rainfall came on July 18th and amounted to one-half inch, resulted in the varieties producing yields less than half the amount in the previous year. As mentioned earlier, it was necessary in this year to curtail the experiment and it was continued with Marquis and Reward only. The 1933 results are shown in Table 3.

TABLE 3.—GRAIN YIELDS IN BUSHELS PER ACRE OF MARQUIS AND REWARD FROM NINE DATES OF SOWING AT SASKATOON IN 1933 AND 1934. EACH YIELD IS THE AVERAGE OF FIVE .00038-ACRE PLOTS ON SUMMER-FALLOW

Variety	Year	Date of sowing								
		April 19	April 28	May 5	May 12	May 19	May 26	June 2	June 9	June 16
Marquis	1933	12.1	15.8	15.4	14.2	14 0	12.7	14.2	11.8	11.9
Reward	1933	9.1	13.7	15.2	13.6	14.4	11.4	14.6	12.4	11.0
		April 20	April 27	May 4	May 11	May 18	May 25	June 1	June 8	June 15
Marquis	1934	23.3	22.7	23.6	23.9	20.1	18.8	18.7	19.1	15.6
Reward	1934	19.6	22.0	23.3	22.8	20.2	19.8	18.1	19.8	16.8

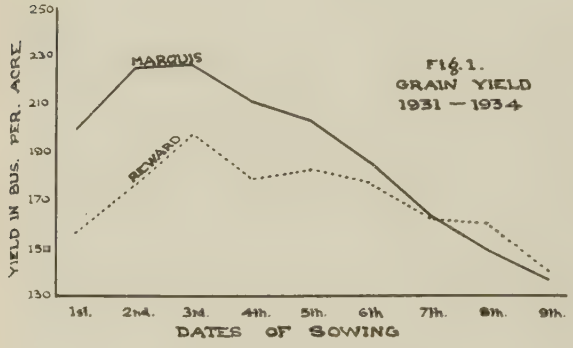
Standard error of mean yield of a variety = 4.5% in 1933 and 3.9% in 1934.

The interaction between varieties and dates was much less striking in 1933 than in the two preceding years, nevertheless it was statistically significant. The two varieties yielded closely alike excepting for the first two dates where Marquis was higher. Use of the standard error of a difference (SE_D) showed that the yield reaction of the two varieties at the second date was significantly different than at the third date. This demonstrates clearly the differential response of the two varieties to the variation in environment which was produced by sowing only one week apart.

1934 Results

In 1934 the experiment was continued as in the previous season. Heavy rains in the fall of 1933 gave the crop a good start despite a very dry spring and the four inches of rain which fell in June resulted in reasonably good yields, although July was very dry. The results are presented in Table 3.

With the exception of the first date, there is little difference between the varietal yields from the different sowings. It is interesting to note that in this year the date of sowing which resulted in the best yield for Marquis is a later one than that at which Reward did its best. As one would expect from an examination of the data, there was no significant interaction between varieties and dates, nor was there a significant difference between the two varieties. However, a SE_D test shows that the spread between the two varieties for the first date is significant; in other words Marquis responded favorably to the environment in which it grew when sown April 20th but Reward did not.



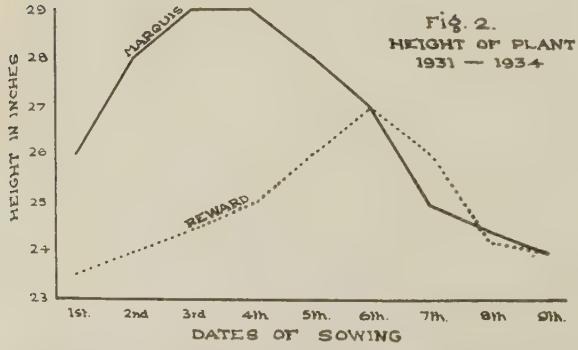


FIGURE 1, grain yield and FIGURE 2, plant height of Marquis and Reward averaged for the four years 1931 to 1934 for each of nine successive weekly dates of sowing, running from April 15 to June 15.

Summarized Results, 1931-1934

Because of the changes made in the experiment in 1932 and 1933 it is not possible to make a simple variance analysis of the four years' results but such an analysis was made on the 1932, 1933 and 1934 data for Reward and Marquis. The tendency of Reward to yield poorly in comparison with Marquis when sown early but to surpass Marquis when sown very late was quite evident.

A variance analysis of the three year's results showed that the interaction of varieties and dates was highly significant. Application of a SE_D test revealed significant differences between the variety differences for the first and third and the second and third dates of sowing. A particularly interesting feature brought out by the variance analysis was the extremely high interaction between varieties and years indicating a large difference in the way the two varieties responded to the different environments under which they grew in the respective seasons. The results for the whole test are summarized graphically in Figure 1.

Owing to the limited scope of this experiment and the fact that the past four years do not constitute an average picture of crop seasons at Saskatoon, it would be difficult and possibly unwise to attempt any specific conclusion as to the best time to sow the different varieties. There was, however, a distinct tendency throughout the test for Reward to reach its best yield when sown one week after the date at which Marquis yielded its best.

HEIGHT

Height of plant, though less important than yield, is of major importance over much of the plains area, particularly in the dry years. Like yield, height is a character which denotes vigor of growth and is therefore well suited for use in this study. Table 4 shows the height of the four

TABLE 4.—PLANT HEIGHTS IN INCHES OF FOUR LEADING WHEAT VARIETIES IN 1931 AND 1932 AND OF MARQUIS AND REWARD IN 1933 AND 1934 FROM NINE DATES OF SOWING AT SASKATOON. EACH HEIGHT IS THE AVERAGE OF FIVE OR SIX .00038-ACRE PLOTS

Variety	Year	Dates of sowing								
		April 21	April 27	May 5	May 12	May 19	May 26	June 1	June 9	June 15
Marquis	1931	17	21	21	25	29	30	27	26	25
Reward	1931	16	16	17	16	21	27	28	25	23
Ceres	1931	16	16	19	20	24	27	27	25	21
Garnet	1931	16	16	16	18	21	26	28	23	21
		April 15	April 26	May 2	May 7	May 14	May 21	May 28	June 4	June 11
Marquis	1932	38	38	39	37	35	32	28	25	26
Reward	1932	32	33	33	31	33	31	29	27	27
Ceres	1932	34	34	36	34	33	32	28	25	25
Garnet	1932	33	34	34	32	32	32	30	29	27
		April 19	April 28	May 5	May 12	May 19	May 26	June 2	June 9	June 16
Marquis	1933	17	20	20	21	20	19	19	20	19
Reward	1933	18	19	19	22	20	19	19	18	20
		April 20	April 27	May 4	May 11	May 18	May 25	June 1	June 8	June 15
Marquis	1934	33	33	35	34	29	28	26	27	26
Reward	1934	28	28	29	32	30	29	27	27	27

Standard errors of mean height of a variety = 4.4% in 1931, 2.8% in 1932, 2.0% in 1933, and 2.3% in 1934.

varieties from each of the nine dates of seeding for the four years of the investigation.

1931 Results

Analysis of the data for 1931 showed that there was a very significant interaction between varieties and dates. Reward, Garnet and Ceres remained remarkably close together throughout the series of nine sowings but Marquis reacted quite differently. Reward, Garnet and Ceres had the same height for the first as for the second date of sowing while Marquis was 25% taller for the second than for the first date. Significant differences between the differences between Marquis and the other three varieties are also shown with respect to the May 26th and June 1st sowings and the June 1st and 15th sowings.

1932 Results

The 1932 results show a significant interaction between dates and varieties. The interaction is similar to that observed for the 1932 yield results, the early varieties being at a disadvantage compared with Marquis when sown very early but at an advantage over Marquis when sown late.

1933 Results

Owing to the drought both varieties were very short in 1933. They were closely alike in height for the whole series of weekly sowings and no interaction of varieties and dates was observable.

1934 Results

For the first three sowings in 1934 Marquis was distinctly taller than Reward but for the last five sowings was a trifle shorter than Reward. The interaction of varieties and dates was highly significant.

Summarized Results for 1931 to 1934

Analysis of the height data for the three years, 1932 to 1934, when the test was randomized on summer-fallow showed a very significant interaction between varieties and dates and between varieties and years. The application of the SE_D test revealed a significant interaction of the varieties for the first and fourth, the second and third, and the third and fourth dates. A graphical summary of the four years' results is presented in Figure 2.

DISCUSSION AND SUMMARY

The study of the comparative reactions of wheat varieties when sown at weekly intervals from April 15 to June 15, in each of four years has demonstrated strikingly that the conditions which favor the growth of one variety may be much less favorable to the development of another one. Significant interactions between varieties and dates of sowing were found for both grain yield and plant height in nearly every year of the experiment. In general the moderately early variety Marquis yielded its best when sown very early in May whereas the very early variety Reward yielded best when sown about one week after the optimum date of sowing for Marquis. The height results showed the Reward optimum attained in sowings made two weeks later than those which gave the tallest Marquis.

The very large differences in the comparative performance of the varieties for both yield and height between the very early and very late

dates may be related principally to the fact that Reward ripens about six days earlier than Marquis. However, there were definite variations within the early dates for Marquis and Reward and significant d fferences with respect to the other varieties, Garnet and Ceres, which cannot be explained solely on the basis of the inheritance concerned with earliness. After all, it is only reasonable to expect that varieties of as diverse origins as the wheat varieties of Western Canada should react quite differently when exposed to a series of different environments.

The distinct differential response of wheat varieties when sown at different dates as established by the results of this study affords a definite basis for the improvement of comparative variety tests. It is evident that a comparative test of varieties at a given location under one set of environmental conditions as provided by sowing all of the varieties at the same date does not furnish a comprehensive comparison of the varieties. This is well illustrated by the fact that Reward did its best when sown later than the optimum date of sowing for Marquis. The results of this study indicate, therefore, that the comparative plot tests of leading wheat varieties, and most probably of other grain crops as well, at the various experimental stations, should be sown, not solely at one date as is the custom now,[5] but at several dates. These tests, if placed at a fairly large number of locations representative of different soil-climatic conditions, should be of immense value as a guide to the practical farmer in answering the questions: what varieties should I grow and when is the best time to sow each variety?

ACKNOWLEDGMENTS

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Résumé

Comportement des variétés de blé semées à différentes dates. J. B. Harrington et W. H. Horner, Université de la Saskatchewan, Saskatoon, Sask.

L'étude du comportement relatif des variétés de blé semées à intervalles d'une semaine, à partir du 15 avril et jusqu'au 15 juin, pendant quatre années de suite, a démontré de façon éloquente que les conditions favorisant la végétation d'une variété peuvent être beaucoup moins favorables au développement d'une autre. Tous les ans ou presque, au cours de cette expérience, on a constaté des différences significatives entre les variétés semées à différentes dates, aussi bien au point de vue du rendement de grain qu'à celui de la hauteur de la plante. En général la variété Marquis, qui est modérément hâtive, a le mieux rapporté lorsqu'elle était semée de très bonne heure en mai, tandis que la variété Reward a le mieux rendu lorsqu'elle était semée à peu près une semaine après la meilleure date pour le Marquis. Les notes prises montrent que le blé Reward a atteint son plus grand développement lorsqu'il était semé à peu près deux semaines après la date des semailles qui avaient

[5] At the meeting of cerealists at the Saskatchewan Agronomic Conference on January 23, 1931, at Saskatoon, Sask., the senior writer urged that successive dates of sowing of leading cereal varieties be made at the various experiment stations of Saskatchewan and, despite the economic depression, the Dominion Experimental Farm at Scott, in addition to the University of Saskatchewan, commenced such a study with wheat varieties.

produit le Marquis le plus développé. Les très grandes différences dans le comportement relatif des variétés, tant au point de vue du rendement que de la hauteur, entre les dates très hâtives et très tardives, peuvent être reliées principalement au fait que le Reward mûrit à peu près six jours plut tôt que le Marquis. Il y avait cependant des variations prononcées entre les premières dates pour le Marquis et le Reward et des différences significatives en ce qui concerne les autres variétés, Garnet et Cérès, qui ne peuvent s'expliquer uniquement sur la base de la transmission héréditaire, au point de vue de la précocité. Après tout, il est raisonnable de croire que des variétés d'origine diverse, comme le sont les variétés de blé de l'Ouest du Canada, réagissent d'une façon très différente lorsqu'elles sont exposées à une série de conditions environnantes différentes. Le comportement différent des variétés semées à différentes dates, établi par les résultats donnés dans cette étude, fournit une base bien nette pour l'amélioration des essais comparatifs de variétés. Il est évident qu'un essai comparatif, effectué à un certain endroit, sous un certain ensemble de conditions environnantes, comme celui que l'on obtient en semant toutes les variétés à la même date, ne fournit pas une juste comparaison des variétés. Ceci est bien démontré par le fait que le Reward a donné les meilleurs résultats lorsqu'il était semé plus tard que la date qui s'était montrée la meilleure pour le Marquis. Les résultats de cette étude indiquent donc que les parcelles d'essai des principales variétés de blé, et tout probablement celles des autres grains aux différentes stations expérimentales, devraient être ensemencées non pas à une même date, comme nous le faisons aujourd'hui, mais à plusieurs dates. Ces essais, répétés à un assez grand nombre d'endroits, représentant différentes conditions de sol et de climat, devraient avoir une valeur immense pour guider les cultivateurs pratiques dans le choix des variétés à cultiver et dans la détermination de la meilleure date de semailles.

SUITABLE CEREALS FOR DRY LAND FARMING ON THE PRAIRIES[1]

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INTRODUCTION

The title of this paper may suggest, on first thought, a discussion of cereal varieties, from the standpoint of their relative ability to produce reasonable yields of grain under drought conditions. This alone would embrace a number of problems involving various environmental factors usually associated with grain growing in our drier areas. The experiences of the past five or six years have, however, emphasized the importance of considering cereals as a necessary and desirable source of fodder and pasture. This fact increases the complexity of the problem before us in so far as it creates a demand, either for cereal varieties of a dual purpose type or for a greater diversity of types to meet all requirements.

The discovery or production of more drought resistant varieties might help in the solution of our problems, but this alone is not enough. Together with drought resistance must be considered other factors of equal importance, such as the ability to resist or recover from the effects of drying winds and drifting soil, to compete successfully with weeds and to survive insect attack. In short, we need to develop varieties that will produce satisfactory crops under a combination of comparatively adverse conditions.

DROUGHT ENDURANCE

In considering the question of drought resistance Maximov (*3*) tells us that "resistance to drought is not due to reduced expenditures of water but to the capacity to endure wilting". Barnes (*1*) states further that "the real test of the drought resistance ability of a crop is its power to yield when moisture is scarce". In experiments conducted at Swift Current, in which crops were subjected to artificial drought conditions until badly wilted and then watered, wheat, oats and barley failed to make any recovery. "These crops appear to adjust their growth as the water supply diminishes. When the low level has been reached, the grains have headed out and have usually produced a small quantity of seed."(*1*).

In areas where moisture is the limiting factor in crop production the water requirement, or efficient use of water by plants, is a very important matter. The comparative water requirement for varieties should be determined in any breeding programme, designed to obtain suitable material for dry land farming. Varieties that are most economical in the use of water are likely to outyield less efficient varieties in the presence of equal amounts of available water when other conditions are equal. Experimental results obtained at Swift Current during the period 1924 to 1929 show that the transpiration ratios for wheat, oats and barley varied from 254 to 501, 270 to 377, and 257 to 526 respectively. These results indicate that the transpiration ratio is not a fixed factor but varies with seasonal conditions.

[1] Paper presented before the Western Canadian Society of Agronomy at the University of Alberta, Edmonton, June 25, 1935.

[2] Acting Superintendent.

[3] Graduate Student Assistant.

TABLE 1.—YIELD OF WHEAT VARIETIES—1930–1934. SWIFT CURRENT, SASK.

Variety	Average yield in bus. per acre	Yield in per cent of Marquis check
Nabawa	19.5*	166.6*
Yandilla King	19.4*	165.8*
Bena	16.8*	138.8*
Reliance	20.8	118.8
Pelissier	19.6	112.6
Ceres	19.6	108.8
Kubanka	18.9	105.6
Mindum	17.9	104.7
Marquis	14.3	100.0
Reward	13.9	79.8

* Two years' results only.

TABLE 2.—YIELD OF OAT VARIETIES—1930–1934. SWIFT CURRENT, SASK.

Variety	Yield in bus. per acre	Yield in per cent of Banner check
Anthony	23.4*	107.3*
Sovereign	23.3*	106.8*
Eagle	40.6†	105.2†
Silver	22.8	104.6*
Markton	39.4	102.8
Victory	36.2	102.8
Banner	28.8	100.0
Gopher	34.5	93.8
Algerian	33.1	92.2

* 1934 only.

† Three years only.

TABLE 3.—YIELD OF BARLEY VARIETIES—1930–34. SWIFT CURRENT, SASK.

Variety	Yield in bus. per acre	Yield in per cent of O.A.C. No. 21 check
Trebi	34.3	213.0
Coast	33.2	207.5
Stavropol	32.2	203.8
Colsess	27.8	155.3
Hannchen	27.8	142.6
Regal	30.7*	135.8*
Sans Barbs Early	20.4*	115.9*
Peatland	9.2†	109.5†
O.A.C. No. 21	20.9	100.0

* Two years only.

† One year only.

Similarly variations may exist between varieties, and those varieties that show the greatest water efficiency under the range of conditions likely to be experienced in the drier areas will undoubtedly be the most desirable. Consequently the problem is to determine what varieties will make the best use of available moisture and if possible to produce new varieties with even lower water requirements.

Yield results at Swift Current during the period 1930 to 1934 should be a good measure of the relative extent to which varieties are adapted to dry land farming. The two preceding years, 1928 and 1929, were both dry and only in 1932 was the annual precipitation equal to the average for the district (15.2 inches). For the seven years 1929 to 1934 the average precipitation was only 11.67 inches of which 6.47 inches fell during the four crop-growing months of April to July. Unfortunately all grain from the tests was lost in a fire in 1931 so that the results presented for wheat and oat varieties are for the four years 1930, 1932, 1933 and 1934. For barley, 1933 results are also omitted due to grasshopper damage.

RECUPERATION FROM SOIL DRIFTING

The soil drifting menace that has accompanied the period of abnormally

dry years has received a very great deal of attention. At the Experimental Station at Swift Current the season of 1934 was marked by particularly severe wind and soil drifting damage to the varietal tests on the experimental area. This condition, while threatening to destroy the tests completely, at one time, made possible valuable comparisons of varieties in regard to their relative wind resistance and recuperative powers. Notes were taken in June on the stands of grain in each plot in our tests of wheat, oats and barley varieties. As these were very greatly influenced by wind and drifting damage it was felt that they represented quite accurately the tenacity of the varieties concerned.

Definite differences existed between varieties. Among the wheats, the durum variety Mindum retained the most nearly complete stand with an average for eight plots of 96%. Nabawa, a white wheat, was second in this regard. This wheat was introduced from Western Australia and is the most popular variety grown in New South Wales, because of its high resistance to flag smut and its high yielding qualities, especially under dry conditions. Reliance proved to be the most resistant of the common hard red spring wheats and stood third for all varieties being followed by Pelissier durum, and two Australian varieties Yandilla King and Bena. Kubanka durum equalled the latter, while Ceres was not far behind. Marquis wheat was represented in the test by three strains Marquis, Ottawa 15; Marquis Ottawa Elite 32 and Marquis Sask. No. 70. These strains and Reward were the least successful in surviving the adverse conditions showing average stands of from 44 to 32 percent of normal.

Variations in average stands of oat varieties were evident also. The most wind resistant variety appeared to be Algerian, a variety that in its early stages retains a comparatively decumbent position and produces a good deal of leaf growth. Other varieties in order of their survival were Silver, Banner, Sovereign and Marvellous. Barley varieties that survived the winds most successfully were Stavropol, Coast and Trebi. Hannchen, the variety recommended for the western half of zone 2 in Saskatchewan, together with Olli was most seriously affected retaining a stand estimated at 26%.

The yield results obtained at Swift Current in 1934 can hardly be considered normal but they are interesting and indicative of the performance of the varieties under adverse conditions. Slight differences existed in the ability of varieties to recover following rains that came in June, but generally speaking a close relationship obtained between June stands and final yield which may best be expressed as correlations. Considering averages for varieties both in stand and yield the correlations are as follows: for the wheat varieties test .87 $\pm$ .03; for the oat varieties test .86 $\pm$ .03; and for barley varieties test .98 $\pm$ .01. These correlations are extremely high and demonstrate the importance of wind resistance in varieties for dry land farming. Yields of the more outstanding varieties and standard varieties should be mentioned. These were as follows:

Wheat varieties		Oat varieties		Barley varieties	
Yandilla King	19.8 bus.	Anthony	23.4 bus.	Stavropol	27.3 bus.
Bena	18.2	Sovereign	23.3	Horne	26.6
Nabawa	17.9	Eagle	23.2	Coast	26.6
Mindum	17.8	Silver	22.8	Trebi	25.8
Pelissier	17.8	Markton	21.9	Colsess	18.7
Reliance	16.4	Banner	21.8	Hannchen	16.4
Reward	8.6	Victory Sel. 25-7	21.5	Peatland	9.2
Marquis O-15	7.6	Algerian	20.7	O.A.C. No. 21	8.4
		Gopher	19.1		

The first three wheat varieties named were introduced from Western Australia. They are white wheats of poor milling and baking quality but may be of value for breeding more productive dry climate wheats. The remarkable recovery of Hannchen barley which gave little promise of producing a crop is of particular interest.

EFFICIENCY IN COMPETING WITH WEEDS

Most of the land in our dry farming areas is badly infested with weeds. Annuals and winter annuals such as Russian thistle, stinkweed and the mustards are particularly common. These have almost as great an influence on the yield of grain as the moisture supply. Experiments at Swift Current have shown that yields may be reduced to 1/3 of the yield of a clean crop by the presence of weeds.

Weeds can be controlled by cultural methods during the summer-fallow year and in the spring preceding seeding. After that the control of weeds is dependent on the ability of the cultivated crop to compete successfully with them. Two factors particularly influence the competitive ability of crops: namely, spring vigour and density as determined by stooling capacity and rate of seeding. The first of these factors is influenced to some extent by the date of seeding and conditions at seeding time. Experiments at Swift Current on dates and rates of seeding of wheat, oats and barley in relation to weed infestation show some interesting results. Wheat seeded about two weeks after the zero date (April 20) gave the best yields. This appeared to be due to destruction of weeds by tillage before seeding and also to the fact that the wheat germinated more quickly and was able to compete more successfully with weeds. Oats and barley on the other hand gave the best results from the early seeding. These tiller more vigorously and were more successful in smothering weed growth. The barley plots were particularly free from any large mass of weeds.

In the rates of seeding tests for wheat, oats and barley three rates were used; namely, 60 lbs., 80 lbs., and 100 lbs., per acre. For all three crops the intermediate rate gave the best yields and was equal to the heavier seedings in effectiveness of weed control. As a result of wet weather in June the plants produced large numbers of tillers. Later many of these dried up causing considerable loss of moisture in the production of fruitless tillers. The greatest loss was sustained from this cause in the heavy seeding with the result that the heads formed on the remaining culms were smaller than those found in the lighter seeding and yields were consequently lower. At harvest time the stands on the medium and heavy seedings were approximately the same.

The light seedings were characterized by lack of uniformity or patchiness in the stands which allowed weeds to thrive. Gaps in the stands were due largely to the inefficiency of the grain drill which is of particular importance where light seedings are made. Tests of a number of grain drills have show that they all allow great variability in the amount of seed delivered per foot of drill run, and that this variability is particularly great in light seedings.

The combined problem offered by the uneven spacing of light seedings and losses through the formation of abortive tillers in heavier seedings presents an opportunity to the plant breeder for improving cereal varieties

for dry land farming. The creation of cereal varieties with low stooling capacity should be of considerable value. Low stooling capacity will help to overcome the mechanical inefficiency of seed drills by allowing thicker sowing and thus provide a uniform covering of crop which would likely make better use of the available moisture for two reasons, namely: (1) offer more effective competition to weeds, and (2) eliminate loss of moisture through the mortality of an excess of tillers thus reserving moisture for the use of the main culms. With varieties that could be depended on to produce a minimum number of tillers per plant, the optimum rate of seeding for prevailing conditions could be more easily determined.

CONTROL OR TOLERANCE OF INSECT DAMAGE

An additional problem of serious proportions is encountered by the cereal grower of the dry land farming area in the presence of two insect pests which at times do severe and widespread damage to cereal crops. These are grasshoppers and the wheat stem sawfly. Grasshoppers become particularly more numerous during the drier periods, while sawfly does appreciable damage every year.

The prevalence of these pests in association with drought conditions makes it necessary to consider them when choosing kinds or varieties of cereals or outlining a breeding programme to meet the needs of dry land farming. Any degree of control that may be effected by judicious choice of varieties or kinds of grain must not be overlooked. Entomologists have observed that the grasshopper (*Melanoplus mexicanus* Saus.) seems to show a greater liking for wheat seedlings than for oat seedlings. When in flight and when cereal crops are nearing maturity, they seem to prefer green oats or barley instead of wheat. Fields of Reward wheat have been reported more seriously damaged than adjoining fields of Marquis wheat. Thus there appears to be some room for investigation as to the relative susceptibility of varieties and kinds of cereals to grasshopper attack at different stages of growth.

Sawfly damage is sometimes severe and widespread. In some seasons parts of fields are infested more than 50% and losses may be considerable to individual farmers. Observations and experiments at Swift Current since 1929 indicate that sawfly damage might be reduced very materially if not entirely eliminated by growing solid stemmed varieties of wheat. Common wheat varieties (*Triticum vulgare*) with the solid stem character are available and the breeding of wheats to include this together with other required and desirable factors would assist in creating varieties more nearly suited to drought conditions.

Observations made at Swift Current in 1934, on caged wheat varieties which were subjected to forced sawfly infestation showed that Marquis wheat was damaged 26%. Solid stem common wheat No. S-615 was damaged 2% and Golden Ball durum also a solid stemmed variety was damaged 1%.

CEREALS AS FODDER OR PASTURE CROPS

As mentioned in the introduction to this paper cereal crops are of considerable importance for their hay and pasture value. Kirk and Davidson (*2*) found that for pasture oats was superior to barley, wheat and spring rye

in yield of dry matter per acre and percentage of protein and gave a very satisfactory yield of hay at Indian Head, Sask. Experiments carried on at Swift Current over a period of ten years demonstrate that cereals are the most dependable source of fodder for the dry farming areas. Annual crops give opportunity for building up moisture reserves by interspersing crops with fallow and so are not so subject to the effect of moisture deficiencies. The difficulty encountered in obtaining a stand of the perennial fodder crops is also a factor.

A comparison of various kinds of cereals grown in one-fiftieth acre plots shows that in yield of cured hay Colsess barley has excelled oats and spring rye by a small margin. In 1934, spring rye came to the fore but a mixture of Banner oats and Colsess barley outyield all varieties grown alone. For palatability and general excellence as a fodder crop oats seem to be the most satisfactory.

In order to explore the possibility of obtaining cereal varieties that are better adapted to use as fodders than those commonly used, some investigational work is going forward. Definite differences in amount of vegetative development have been noted between varieties of both barley and oats, but varietal yield trials have not been carried far enough to give any conclusive results.

CONCLUSION

The problem of cereal crop production under drought conditions on the prairie is often intensified by associated competitive or destructive agencies such as weeds, soil drifting and insect pests. These additional factors must be carefully considered in the development of a breeding program, if it is to meet the demands of dry land farming and give greater security in cereal crop production.

REFERENCES

1. Barnes, S. and E. S. Hopkins. Soil moisture and crop production. Dom. Dept. of Agr. Bull. 130 N.S. 1930.

2. Kirk, L. E., J. G. Davidson and Stella N. Hamilton. Cereal grain crops for annual pasture. Sci. Agr. *15* : 569-579. 1934.

3. Maximov, N. A. A textbook of plant physiology. McGraw-Hill, New York. 1930.

THE INFLUENCE OF ENVIRONMENT UPON THE GERMINATION OF WEED SEEDS[1]

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INTRODUCTION

To become a serious pest under the climatic conditions and cropping practices of Western Canada, it is necessary for an annual weed to have a period of dormancy for its seeds, and to require exacting conditions for their germination. Irrespective of competing ability and other plant habits, it is only by such a mechanism of dormancy and germination that an annual weed species may perpetuate its kind over long winters and years of summer-fallow.

The successful control of annual weeds necessitates the germination of viable weed seeds in the soil. A knowledge of the conditions under which weed seeds will or will not germinate should therefore greatly assist the farmer in his weed control program.

A review of literature indicates that the germination of seeds may be influenced by: (1) the condition of the seed with respect to dormancy, (2) temperature, (3) oxygen, and (4) moisture. Each of these factors will be discussed separately, although, under field conditions, the problem of weed seed germination involves a combination of them all.

THE CONDITION OF THE SEED WITH RESPECT TO DORMANCY

The work of Atwood (*2*), Crocker (*4, 5*), Crocker and Davis (*6*), Kidd and West (*8*) and others has shown that many different factors may be responsible for the dormancy of seeds. As the determination of these factors is very complex, no attempt was made in the present study to ascertain the causes of dormancy for the different weed seeds studied. The factors for dormancy, together with those which may break dormancy, as found by the above workers, have, however, been of great assistance in interpreting the data obtained in this study.

Low temperatures, and alternate freezing and thawing are given by Crocker as factors which may break the dormancy of seeds. Observations at Saskatoon support this, and indicate that climatic conditions during the winter remove to a considerable extent the dormancy of weed seeds in the soil. The results show that if weed seeds are in a favorable position in the soil for germination, a large percentage will do so in the spring.

THE INFLUENCE OF TEMPERATURE UPON THE GERMINATION OF WEED SEEDS

The temperature of the soil may have an influence upon the germination of weed seeds throughout the season, but its greatest differential effect on seeds of different species is in the spring, when the weed seeds germinate after remaining dormant all winter. Aamodt (*1*) recently reported Russian Pigweed seeds germinating upon ice and frozen soil,

[1] This study is part of the attack on the weed problem of Canada. The results were reported in a paper before the Western Canadian Society of Agronomy at the University of Alberta, Edmonton, June 24–26, 1935. The study was made under the direction of Dr. J. B. Harrington, whose advice and helpful criticism throughout the course of the study is appreciated greatly.

[2] Graduate Student Assistant.

in March, 1934, while seeds of cereal crops were still dormant. Observations at Saskatoon in 1933 showed there was a wide variation in the time when seedlings of different weed species first emerged in the spring. In 1934 and 1935 further observations were made upon this point, and in Table 1 the dates of first emergence for different weed species are compared with the dates of emergence for different cereal crops sown as early as possible in the spring.

TABLE 1.—THE SEQUENCE OF EMERGENCE OF ANNUAL WEEDS AND CEREAL CROPS IN THE SPRING AT SASKATOON IN 1935

Date of emergence		Weed
1935	1934	
April 12	April 12	Knotweed (*Polygonum aviculare*, L.)
April 13–17		No emergence.
April 18	April 18	Russian Pigweed (*Axyris amarantoides*, L.)
April 19		Stinkweed (*Thlaspi arvense*, L.)
April 19	April 20	Russian thistle (*Salsola Kali*, L.)
April 20		Lamb's Quarters (*Chenopodium album*, L.)
April 21	April 24	Wild Mustard (*Brassica arvensis*, Ktze.)
April 22	April 24	Hares-ear Mustard (*Conringia orientalis*, Dumort.)
April 23		No emergence.
April 24		Tumbling Mustard (*Sisymbrium altissimum*, L.)
April 25	April 24	Prolific Spring Rye (*Secale cereale*, L.)
April 26	April 25	Hannchen Barley (*Hordeum distichon*, L.)
April 27	April 26	Marquis Wheat (*Triticum vulgare*, vill.)
April 28		Reward Wheat (*Triticum vulgare*)
April 28	April 26	Banner Oats (*Avena sativa*, L.)
April 29	April 26	Wild Buckwheat (*Polygonum Convolvulus*, L.)
April 30–May 2		No emergence.
May 3	May 4	Wild Oats (*Avena fatua*, L.)
May 4–10		No emergence.
May 11		Red-root Pigweed (*Amaranthus retroflexus*, L.)

NOTE.—The date is for the first emergence of weeds, and 25% emergence of cereal crops. Each cereal crop figure is the average of six replicates sown April 12.

The results show that under conditions present at Saskatoon during the springs of 1934 and 1935, a number of weed species emerged before the earliest sown cereals had emerged.

In 1932 the findings of Pavlychenko and Harrington (*9*) demonstrated that cereal crops which secured an early start over weeds may compete successfully with them throughout life, but that when the weeds made the earlier start, weedy fields generally resulted. It would therefore appear that a safe procedure would be to delay sowing the cereals on soil polluted with weed seeds, until a crop of weeds has germinated and has been destroyed by cultivation.

THE EFFECT OF OXYGEN UPON THE GERMINATION OF WEED SEEDS

The work of Hutchins (*7*) shows that seeds differ greatly in the rate at which they require oxygen for germination, and that soils may be so compacted by rain, that their "oxygen supplying power" is below that necessary for the germination of seeds of some species. Cereal crops were shown to germinate with an oxygen supply equivalent to 2 m.g. per metre per hour, while seeds of black mustard (*Brassica nigra*, L.) required eleven times that rate before they would start growth.

An experiment was conducted at Saskatoon to ascertain the extent to which lack of oxygen might influence the dormancy of weed seeds under field conditions. Seeds of wild oats and wild mustard were mixed with the top three inches of soil in a plot 6 feet × 36 feet. The soil was then well compacted by watering. Two weeks later any weeds which had germinated were destroyed by shallow hoeing, and strips across the plot were cultivated with a spade. Table 2 shows the number of seedlings per two square feet which grew upon the tilled and untilled plots 15 days after the cultivation.

TABLE 2.—THE GROWTH OF SEEDLINGS UPON TILLED AND UNTILLED SOIL. SASKATOON, 1934

Replicate	Number of seedlings per two square feet			
	Wild oats		Wild mustard	
	Tilled	Untilled	Tilled	Untilled
1	22	1	23	6
2	18	3	19	6
3	7	1	11	14
4	9	4	27	14
5	9	2	19	8
6	19	3	18	12
7	30	3	8	9
8	34	6	28	13
Mean	18	3	19	10
S.E. mean	±3.15	±0.49	±3.24	±1.74
Difference*	15		9	
S.E. diff.*	±3.2		±3.7	
% increase due to tillage	500%		90%	

*The difference in each case between the "tilled" and "untilled" results is greater than twice the S.E. diff. (standard error of a difference), consequently both differences are considered to be significant.

Nearly seven times as many wild oats and twice as many wild mustard seedlings grew upon the tilled soil as upon the untilled, thereby indicating that soil aeration may be an important factor in the germination of seeds of these weeds.

These results indicate that the practice of leaving the fallow uncultivated, and keeping the weeds down by pasturing, would, from the view point of germination result in relatively little decrease in the weed seed content of the soil, and that sufficient cultivation should be given the fallow soil, especially in the more humid areas, to ensure sufficient aeration for the germination of the weed seeds.

A report from a farmer upon the Regina clay type of soil indicates that lack of aeration may affect considerably the germination of weeds in that area. A field summer-fallowed the previous year was sown to wheat in the spring. Half the field was tilled previous to seeding while the remainder was not. At harvest time the cultivated area was heavily infested with wild mustard, while that not disturbed previous to seeding was comparatively free. It would seem that lack of aeration prevented the weed seeds from germinating upon the untilled soil while cultivation

resulted in ideal conditions for their growth. Chepil (*3*) emphasises this point in recommendations from Regina Experimental Sub-station as follows: "It has been found that implements which bring up dormant seed from below the second or third inch should not be used ahead of the drill. . . . . If the fallow is clean and firm, seeding directly without previous tillage proved successful."

The problem of lack of sufficient aeration for seed germination is largely confined to the heavier types of soil and may explain the persistance of mustard and stinkweed on clay and heavy loam soils.

Observations in 1933 showed that where wild mustard seeds had shattered upon the ground many seedlings had grown, even though there was no tillage to cover the seeds. From this it seemed possible that seeds of some weeds might germinate more readily if they were not covered by fall tillage, and experiments were conducted to determine the value of that cultural operation from the view point of weed seed germination. Seeds of stinkweed, wild mustard and wild oats, harvested from the 1934 crop were scattered upon a plot 6 feet by 36 feet on September 10 of that year. Strips across this plot were then cultivated with a spade, the soil being turned about three quarters over as might be done with a disc. Favorable rains in September resulted in good fall germination. The number of seedlings which had emerged one month later is shown in Table 3, while Table 4 shows the number which grew in the spring of 1935.

TABLE 3.—THE EFFECT OF FALL TILLAGE UPON WEED SEED GERMINATION, SASKATOON, SEPTEMBER, 1934

Replicate	Seedling counts per two square feet					
	Wild oats		Wild mustard		Stinkweed	
	Tilled	Untilled	Tilled	Untilled	Tilled	Untilled
1	22	0	104	17	11	1
2	24	4	58	74	5	8
3	22	0	29	13	1	31
4	11	0	20	103	2	5
5	13	8	35	59	4	48
6	17	9	67	25	18	78
7	12	4	32	229	1	18
8	25	10	115	131	0	104
9	38	0	73	13	0	30
Mean	20	4	59	74	5	36
S.E. mean	±7.3	±1.4	±21.3	±26.6	±1.7	±12.9
Difference*	16		15		31	
S.E. diff.*	±7.4		±34.1		±13.0	
% increase due to tillage	400%		−20%		−86%	

NOTE.—Seed scattered on ground surface.....Sept. 10, 1934.
Strips across plot cultivated.....Sept. 12, 1934.
Counts taken.....Oct. 14, 1934.

*The tilled vs. untilled difference for Wild Mustard is not significant.

TABLE 4.—THE EFFECT OF FALL TILLAGE UPON WEED SEED GERMINATION, SASKATOON, MAY, 1935

Replicate	Seedling counts per square foot area					
	Wild oats		Wild mustard		Stinkweed	
	Tilled	Untilled	Tilled	Untilled	Tilled	Untilled
1	6	0	53	45	100	122
2	6	0	34	59	166	217
3	10	0	37	116	131	59
4	10	0	76	99	241	203
5	11	0	15	97	85	260
6	4	0	36	29	74	120
7	5	0	12	99	170	309
8	3	0	78	84	36	23
9	6	0	45	95	224	462
10	6	0	82	127	160	467
11	3	0	107	72	125	681
12	2	0	117	28	213	556
13	9	0	67	155	191	503
14	7	0	126	142	54	203
15	7	0	210	83	81	336
16	4	0	108	34	47	396
17	3	0	117	4	210	152
18	2	0	17	21	146	196
Mean	6	0	74	77	136	292
S.E. mean	±0.58	–	±7.4	±7.7	±13.6	±29.2
Difference*	6		3		156	
S.E. diff.*	±0.58		±10.7		±32.3	
% increase due to tillage	α		−4%		−53%	

NOTE.—Seeds scattered on ground surface.....Sept. 10, 1934.
Strips across plot cultivated.....Sept. 12, 1934.
Counts made.....May 13, 1935.

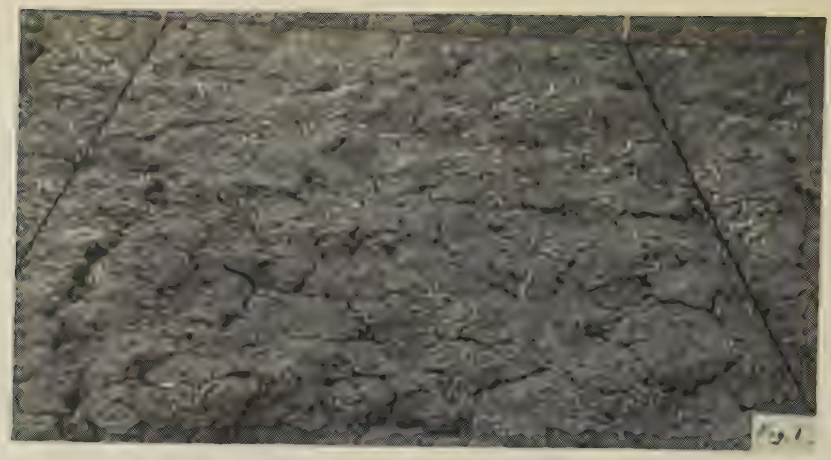
*The tilled vs. untilled difference for Wild Mustard is not significant.

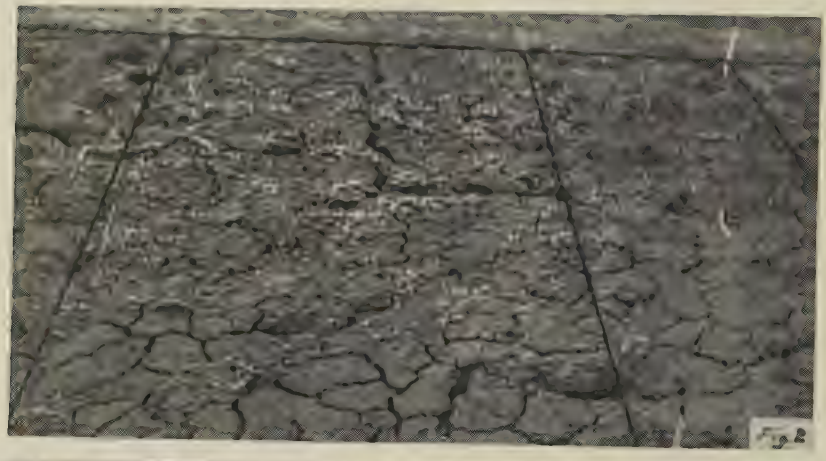
As these tables show, wild oats were greatly favored by fall tillage, while stinkweed germinated better when lying upon the ground surface. The fall tillage did not significantly influence the wild mustard germination.

Figures 1, 2 and 3 illustrate the spring growth of stinkweed and wild mustard seedlings in the fall tilled and the untilled plots.

From observations made in 1934 it seems that seeds of the size of wild mustard and stinkweed upon shattering may penetrate the dust mulch upon the ground surface sufficiently to place them in an ideal location for germination if rain should fall. Seeds of wild oats on the other hand collected in the depressions and cracks in the soil, but no germination was observed from such seed, except where they had worked their way well into cracks.

The value of fall tillage from the point of view of weed seed germination is possibly influenced greatly by climatic and soil types. Under cool moist weather conditions and on a medium clay loam soil the results from this experiment would indicate that fall tillage as widely practiced for the control of wild oats is justified. Such tillage, however, may be detrimental to the germination of some of the small seeded weeds.





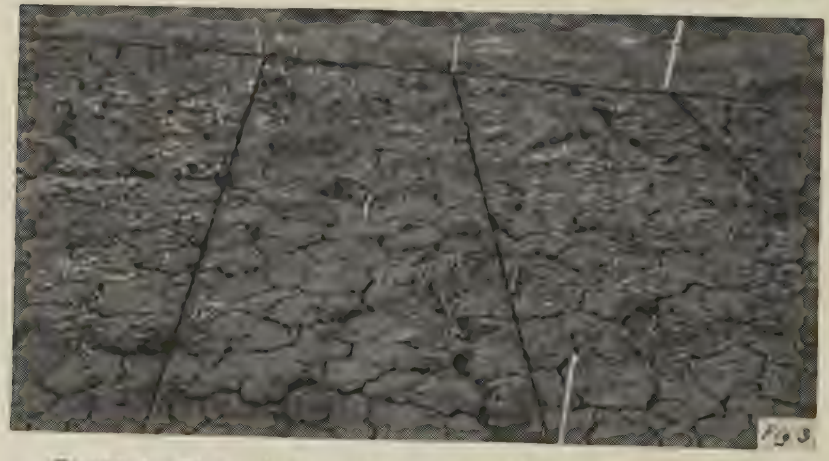


FIGURE 1. The spring growth of stinkweed and wild mustard seedlings on fall tilled soil. The dark lines represent the divisions between the fall tilled plots and the untilled plots at either side.

FIGURE 2. The spring growth of the same weeds in plot where the seeds were left upon the ground surface. Cultivated plots are on either side of the untilled one.

FIGURE 3. The plots in this figure, reading from left to right, are: (1) untilled, (2) tilled, (3) untilled, (4) tilled. Note that although these pictures were taken about May 9th, there is no indication of wild oat emergence.

EFFECT OF SOIL MOISTURE UPON THE GERMINATION OF WEEDS

The limiting factor in weed seed germination over a large part of Western Canada is moisture. During the last few years, many farmers have been disappointed at the failure of summer-fallow to reduce the number of annual weeds. Lack of sufficient moisture in the surface soil to support germination is largely the cause of this. It is imperative that farmers not only conserve moisture in the sub-soil for the succeeding crops, but also utilize efficiently the limited amount of moisture which may fall as rain, for the germination of weed seeds in the soil.

A study was made of the effect that different tillage operations in hot dry weather had upon the moisture content of the surface soil. As many weed seeds germinate very readily, and others will only germinate from the top two inches of soil, sufficient moisture to support germination in that layer is desirable. Preliminary moisture determinations of disced and undisced soil were made in 1934 with the results shown in Table 5. The results for the more comprehensive studies undertaken in 1935 are given in Table 6.

TABLE 5.—THE INFLUENCE OF DISCING UPON THE MOISTURE CONTENT OF THE SURFACE SOIL, SASKATOON, 1934

Date of treatment	Treatment	Depth in inches	Per cent moisture on air dry basis on	
			April 18	April 22
April 17	Check	0–1	15.6	9.36
	Check	1–2	21.5	19.11
	Disced	0–1	14.7	4.35
	Disced	1–2	18.0	7.14
			May 22	May 26
May 22	Check	0–1	3.8	1.8
	Check	1–2	14.6	12.8
	Disced	0–1	3.2	1.0
	Disced	1–2	13.7	4.3

METEOROLOGICAL DATA, FROM THE DEPT. OF PHYSICS, UNIVERSITY OF SSAKATCHEWAN

Date	April						May				
	17	18	19	20	21	22	22	23	24	25	26
Temp. Max. ° F.	56.8	52.5	58.0	80.1	76.9	65.0	62.5	64.5	78.9	86.4	90.2
Min. ° F.	29.1	31.0	25.6	30.5	43.5	36.0	49.0	35.0	38.0	50.0	61.0
Wind. Av. Vel. m.p.h.	15.9	15.0	9.9	13.7	14.5	20.8	8.9	8.0	10.2	11.3	9.0
Precipitation, in.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

The plot layout in 1934 consisted of alternate strips of d sced and undisced soil upon fall cultivated stubble. Composite samples, each representative of four samplings were then taken from the disced and undisced plots. For each sample from the tilled plot a corresponding sample was taken from the untilled plot three feet away.

In 1935 different types of tillage were performed in strips across a fallow field. Uncultivated strips four feet wide were left as check plots. Duplicate composite samples were taken at each depth on two different areas of each plot. The sampling procedure was essentially the same to that used in 1934.

TABLE 6.—THE INFLUENCE OF DIFFERENT TILLAGE OPERATIONS UPON THE MOISTURE CONTENT OF THE SURFACE SOIL. DETERMINATIONS MADE AT 1 AND 4 DAYS AFTER TREATMENT. SASKATOON 1935

Date	Depth of sampling, inches	Sample No.	% moisture on air dry basis							
			Disced	Check	Disced and packed	Harrowed	Check	Rod weeder	Cultivated	Check
July 12 8 a.m.	0–1	A1	6.6	7.0	4.5	4.0	4.6	2.6	4.0	5.8
		A2	4.8	6.2	2.3	4.3	4.0	3.0	3.5	6.8
		B1	7.3	8.6	6.8	4.8	6.2	2.4	5.0	5.6
		B2	8.2	6.8	7.1	7.2	6.6	2.1	4.2	5.6
		Mean	6.7	7.2	5.2	5.1	5.4	2.5	4.2	6.0
		Diff. from nearest check	0.5		2.0	0.3		2.9	1.8	
		S.E. diff.*	±0.64		±0.58	±0.40		±0.40	±0.40	
	1–2	A1	10.8	15.4	13.6	14.0	15.2	12.2	10.8	15.3
		A2	11.4	16.0	13.4	15.0	15.2	13.3	12.0	15.9
		B1	15.2	17.1	15.1	16.5	15.2	11.8	12.6	14.9
		B2	15.6	16.8	16.4	16.4	15.8	12.3	12.0	14.1
		Mean	13.2	16.3	14.6	15.5	15.4	12.4	11.8	15.0
		Diff. from nearest check	3.1		1.7	0.1		3.0	3.2	
		S.E. diff.*	±1.38		±1.44	±1.41		±1.31	±1.25	
July 15 8 a.m.	0–1	A1	0.1	1.0	0.0	0.0	1.2	0.5	0.4	1.0
		A2	0.1	1.0	0.0	0.6	1.2	0.8	0.3	2.0
		B1	0.9	2.5	2.9	1.6	3.9	1.4	1.6	3.3
		B2	0.2	3.6	2.6	4.2	3.8	1.0	0.2	2.3
		Mean	0.3	2.0	1.4	1.6	2.5	0.9	0.6	2.2
		Diff. from nearest check	1.7		0.6	0.9		1.6	1.6	
		S.E. diff.*	±0.13		±0.16	±0.20		±0.18	±0.15	
	1–2	A1	3.9	12.1	10.4	10.8	14.0	11.0	9.0	14.0
		A2	4.0	12.6	11.6	12.1	13.8	10.8	11.1	13.4
		B1	9.6	15.4	15.1	14.3	14.5	12.5	9.7	13.2
		B2	10.0	15.0	14.2	15.1	14.0	13.0	9.0	12.9
		Mean	6.9	13.8	12.8	13.1	14.1	11.8	9.7	13.4
		Diff. from nearest check	6.9		1.0	1.0		2.2	3.7	
		S.E. diff.*	±1.01		±1.24	±1.23		±1.21	±1.07	

Cultivations—July 11, 8 a.m.

*A difference twice the S.E. diff. is significant.

S.E. mean in % = ±6.61.

METEOROLOGICAL DATA FROM THE DEPT. OF PHYSICS, UNIVERSITY OF SASKATCHEWAN

Date	July				
	11	12	13	14	15
Temperature, ° F. Max.	77.7	82.7	85.0	87.5	95.0
Min.	56.8	54.8	58.4	58.0	55.1
Wind. Av. Vel. m.p.h.	7.9	14.0	10.2	11.6	7.5
Precipitation, inches	0.04	0.0	0.0	0.0	0.0

The 1934 results, although of a preliminary nature, show a more rapid loss of moisture from the disced soil than from the undisced. The results for 1935 support the 1934 findings and indicate that this loss might be prevented by packing after the discing. The practibility of such packing from a weed control standpoint is doubtful, but the results illustrate the value of packing in the preparation of a seed bed for small seeded crops. The 1935 results also show that cultivation is conducive to rapid loss of moisture from the surface soil if it is done in hot dry weather.

As it takes at least 12% of moisture to support germination on the medium clay loam where these tests were conducted, the tillage with the disc or cultivator was instrumental in reducing the moisture of the surface soil below that necessary for the germination of weed seeds.

Tillage in warm dry weather is frequently necessary for the destruction of growing weeds. However, the results of these experiments show that it may prevent weed seed germination; therefore unnecessary tillage, such as the maintenance of the soil mulch on clean summer-fallow, and cultivation shortly after a rain favorable for weed seed germination, should be avoided.

SUMMARY

1. A study was made of weed seed germination as influenced by (1) the condition of the seed with respect to dormancy, (2) temperature, (3) oxygen, and (4) moisture.

2. Seedlings of several common weed species emerged in the spring distinctly earlier than the earliest sown spring grains. This suggests the need of destroying a crop of weeds in the spring before sowing the crop. Wild oats and redroot pigweed on the other hand germinated later than the cereal crops.

3. Experiments showed that aeration of the soil by tillage encouraged the germination of weed seeds lying dormant in the soil. Covering of seeds by tillage in the fall was shown to encourage wild oat germination and suppress that of stinkweed. The covering of wild mustard seeds did not influence the germination significantly.

4. Moisture determinations made upon fields after tillage showed that the stirring up of the surface soil in hot dry weather by implements hastened the drying out of that soil sufficiently to prevent weed seed germination. Unnecessary tillage upon the summer-fallow would therefore appear to be detrimental to weed seed germination.

REFERENCES

1. Aamodt, O. S. Germination of Russian pigweed upon ice and on frozen soil. Sci. Agric. *15* : 507-508. 1935.

2. Atwood, W. M. A physiological study of the germination of *Avena fatua*. Bot. Gaz. *57* : 387-414. 1914.

3. Chepil, W. S. Shallow tillage is key to annual weed control. Saskatchewan Farmer, March 1, 1935.

4. Crocker, Wm. Mechanics of dormancy of seeds. Am. Jour. of Bot. *3* : 99-120. 1916.

5. ————————. Points of agronomic interest in the physiology of germination. Jour. Am. Soc. Agron. *17* : 696-704. 1925.

6. ———————— and Davis, W. E. Delayed germination in seeds of *Alisma Plantago*. Bot. Gaz. *58* : 285-321. 1914.

7. Hutchins, L. M. Studies on oxygen-supplying power of the soil, together with quantitative observations on the oxygen-supplying power requisite for seed germination. Plant Physiology, *1* : 95-150. 1926.

8. Kidd, E. and West, C. Controlling influence of CO_2. Ann. Bot. *31* : 457-487. 1917.

9. Pavlychenko, T. K. and Harrington, J. B. Competitive efficiency of weeds and cereal crops. Can. Jour. Res. *10* : 77-94. 1934.

Résumé

Effet des conditions environnantes sur la germination des graines de mauvaises herbes. R. O. Bibbey, Université de la Saskatchewan, Saskatoon, Sask.

Il a été fait une étude de l'effet exercé sur la germination des graines de mauvaises herbes par (1) l'état plus ou moins dormant de la semence, (2) la température. (3) l'oxygène et (4) l'humidité. Les tigelles de différentes espèces de mauvaises herbes communes ont levé beaucoup plus tôt au printemps que les grains les premiers semés. Ceci montre qu'il est nécessaire de détruire les mauvaises herbes avant de semer la récolte au printemps. D'autre part, la folle avoine et l'amarante à racine rouge ont germé plus tard que la récolte de céréales. Il a été démontré par des expériences que l'aération du sol par les binages encourage la germination des mauvaises herbes qui sont dormantes dans le sol. On a constaté que le recouvrement des graines par un hersage en automne encourage la germination de la folle avoine et supprime celle du tabouret. Le recouvrement des graines de moutarde sauvage n'a pas beaucoup influencé leur germination. Les déterminations d'humidité qui ont été faites dans les champs après les hersages ont démontré que le scarifiage de la surface du sol par un temps chaud, active le dessèchement du sol suffisamment pour empêcher la germination des mauvaises herbes. Il semble donc que les façons aratoires inutiles sur jachère d'été retardent la germination des graines de mauvaises herbes.

ROOT DEVELOPMENT OF WEEDS AND CROPS IN COMPETITION UNDER DRY FARMING[1]

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INTRODUCTION

Plant competition is a natural phenomenon, in which plants of the same or unrelated species growing in close proximity develop at the expense of their weaker rivals. The phenomenon is of general occurrence in the plant kingdom both among native species under natural conditions and between crops and weeds in cultivated fields. Under dry farming conditions plant competition is intensified as the amount of available moisture is nearly always quite limited and the full capacity of plants to utilize soil moisture is rarely satisfied.

In the weed research which has been carried on at the University of Saskatchewan for the past five years much emphasis has been laid on the problems of plant competition and especially on competition involving weeds and crop plants. The present paper will present the results of studies dealing with competition in its relations to the struggle for available moisture.

PROCEDURE

The studies described in this paper were made on material grown during the years 1931 to 1935 on the chocolate loam of the Weed Nursery of the University Experimental Farm at Saskatoon. The usual field plot technique was used in the planning and care of the experiments. The excavation, washing, and analysis of the root systems was conducted according to the special method briefly described by Pavlychenko and Harrington (*3*) in 1934. Where single plants were grown alone for comparison with plants grown in drill rows, the two sets of material were seeded on the same half-acre field on the same day under as closely similar soil and other external growth conditions as possible.

INTENSITY OF PLANT COMPETITION

Plant competition is not known to take place where the plants are spaced so far apart that their root systems do not meet under the ground, but its effects may be observed as soon as the spacing between the neighboring plants is reduced to the extent that their root systems commence to occupy the same feeding ground. Observations over a period of several years in the Weed Nursery at Saskatoon indicate that competition between overlapping root systems takes place long before the tops begin to shade one another. As this point is still a subject of debate, the results of an experiment conducted at Saskatoon in 1935 will be of interest.

The experiment consisted of a study of hare's ear mustard *(Conringia orientalis)* when grown under different intensities of competition. Hare's ear mustard was chosen for the study on account of its non-branching

[1] A paper presented before the Western Canadian Society of Agronomy at the University of Alberta, Edmonton, June 26, 1935. This study forms a part of the attack on the weed problem in Canada and was made possible by financial assistance from the National Research Council.

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habit which reduces to a minimum the probability of shading between neighboring plants occurring at early growth stages. The plants were grown under three widely different densities of population varying from one plant per square yard to 3430 per square yard. In each case the plants were excavated at 25 days after emergence before the tops began to shade one another.

TABLE 1.—DEVELOPMENT OF TOP GROWTH AND ROOT SYSTEMS OF PLANTS OF HARE'S EAR MUSTARD WHEN GROWN IN 1935 UNDER DIFFERENT INTENSITIES OF COMPETITION AND EXCAVATED AT 25 DAYS AFTER EMERGENCE BEFORE THE TOPS BEGAN TO SHADE ONE ANOTHER

Characters studied	Intensity of competition		
	None (1 pl. per sq. yard)	Moderate (108 pls. per sq. yard)	Very severe (3430 pls. per sq. yard)
Height in inches	11	6.0	0.5
Total assimilation leaf surface in sq. inches	156	6.8	0.6
Diameter across tops in inches	6	2.5	0.8
Diameter across the root system in inches	34	21.0	8.0
Total linear length of the root system in inches	17400	6611.0	203.0

The results are given in Table 1 and demonstrate clearly that severe competition occurred, although shading of one plant by another was absent. The plant growing alone in a square yard area had a height of 11 inches with a total assimilation leaf surface of 156 square inches and a total length of root system of 17,400 inches; the corresponding figures for an average plant from the square yard containing 108 plants were 6 inches in height, 6.8 inches of leaf surface, and 6,611 inches of root system; where 3,430 plants grew together on a square yard area they averaged only one-half inch in height with 0.6 of a square inch of assimilation leaf surface and a total root length of 203 inches. It is apparent that the striking differences in the top growth should be attributed entirely to the competition occurring beneath the soil surface.

EFFECT OF WEED COMPETITION ON WHEAT

Competition develops around the so called "primary growth factors" of which three are highly important under dry farming conditions, namely: water, light and nutrients, as has been shown by Clements, Weaver and Hanson (*2*). Any one of the three may be a limiting factor if it is present in an amount insufficient to the needs of plants. In the prairie portion of Western Canada, where light is generally plentiful and the soil fertility is not greatly depleted, water is usually the limiting growth factor.

Barnes and Hopkins (*1*) after an investigation into the water requirements of crops in Western Canada, concluded that a crop is able to utilize as much water as it can secure. There is seldom an abundance of moisture in soils of the open prairie, and plant growth usually takes all that is available whatever that amount may be. This being the case a grain crop which shares the available moisture with weeds would be expected to suffer at least to the extent that the weeds thrived.

In an experiment at Saskatoon a clean field plot of Marquis wheat yielded in the very dry year of 1933 a total of 1342 pounds of straw and no grain. The drought was so severe that it stopped the crop's development at heading time. A comparable field plot of Marquis infested with wild mustard yielded only 862 pounds of straw and no grain. In 1934, a fairly favorable season, the same clean land used in 1933 gave a Marquis yield of 45 bushels of plump grain per acre whereas Marquis on the land infested with wild mustard yielded only 27 bushels per acre of slightly shrunken grain. The results appear in Table 2. The last column of the table shows the percentage reduction in yield due to the weed competition. It is interesting that the reduction was almost identical in the two cases.

TABLE 2.—REDUCTION IN YIELD OF MARQUIS WHEAT *(Triticum vulgare)* DUE TO INFESTATION OF WILD MUSTARD *(Brassica arvensis)* ON CHOCOLATE LOAM SOIL AT SASKATOON

Year	Character of season	Land condition		Difference in per cent
		Clean	Weedy	
1933	Very dry	1342 lbs. of straw. No grain	862 lbs. of straw. No grain	36
1934	Average	45 bushels	27 bushels	40

EFFECT OF COMPETITION ON ROOT AND TOP DEVELOPMENT

Competition between plants for water is carried on through their root systems. The roots are the first organs to support new life developing from the seed and their rôle in the plant's life cannot be over emphasized. Observations of many thousands of plants grown in competition at Saskatoon, Saskatchewan, show that only the individuals which develop healthy and extensive root systems soon after germination grow normally until maturity. The plants with weak or defective roots, on the other hand, frequently die before emergence, or if emerged they remain weak or die from competition with stronger neighbors before maturity. Knowledge of the extent, penetration and distribution of root systems of different crops and important weed species is extremely limited due largely to the fact that the roots are hidden in the soil and not easy to study. Yet such knowledge is essential if recommendations with regard to choice of crop and methods of handling are to be on a proper scientific basis. Weaver and Fitzpatrick (*4*) in a monograph on the native vegetation of the Great Plains Area of the United States states that "the bulk of the prairie is below and not above the ground." The Weed Nursery investigations at Saskatoon during the past five years have indicated that at least half of a cultivated crop is also below the surface. It, therefore, is highly important to learn more about the quantitative relations between the top and underground development of the crop and weed plants which occupy the fields of the Western Canadian Prairies.

An extensive study has been in progress for five years at the Weed Nursery for the purpose of investigating the root and top development of weed and crop plants when grown alone free from competition and when grown in close competition with other plants of the same or different

kinds. The object in studying the root systems of single plants of cereals and weeds free from all competition was to provide material with which to compare the root systems of plants grown under various intensities of competition and thereby to express the full effects of competition on their development.

The results are presented in Tables 3 and 4. Plants grown alone each in an area ten feet square produced very extensive root systems and top growth as compared with the development of plants under competition with other plants of the same or unrelated species. Normally, however, plants grow in competition with others, consequently the comparison of the different species when grown in drill rows is of principal interest. The results in the three tables show large differences between species.

TABLE 3.—COMPARATIVE RESULTS FROM ROOT AND TOP DEVELOPMENT OF MATURE SINGLE PLANTS GROWN FREE FROM COMPETITION (TEN FEET APART IN ALL DIRECTIONS) AND PLANTS GROWN IN CLOSE COMPETITION IN DRILL ROWS UNDER ORDINARY FIELD CONDITIONS IN 1932

Plants Studied	Single plants grown alone			Average of competing plants†	
	Roots		Top	Roots	Top
	Total length in feet	Root system diameter in feet	Dry matter in grams	Total length in in feet	Dry matter in grams
Russian thistle *(Salsola kali)*	*	17.2	1662	81	0.5
Common wild mustard *(Brassica arvensis)*	*	11.0	228	117	1.5
Hare's Ear mustard *(Conringia orientalis)*	*	5.4	195	52	0.25
Wild oats *(Avena fatua)*	7987	2.1	58	841	5.2
Marquis wheat *(Triticum vulgare)*	1477	1.9	28	162	0.6
Hannchen barley *(Hordeum distichum)*	6917	2.3	43	770	4.7

*The root systems of single weed plants grown free from competition were too large to excavate satisfactorily and ascertain the total length; consequently the size of these root systems is shown only by referring to their lateral spread.

†There were from 18 to 20 plants per foot of row in each case.

Table 3 shows comparative results on wheat, barley, and four weed species. The six different species gave essentially the same wide contrasts between plants with and without competition. Single plants of wild oats, Marquis wheat and Hannchen barley had approximately nine times as much total length of root system when grown alone as when grown in six-inch drill rows. Approximately the same spread occurred also with respect to top development. Under dry farming conditions weeds occasionally get the opportunity to develop with little or no competition and attain the huge proportions indicated by the root diameters given in the second column of the table. While cereal crop plants seldom have the opportunity, the figures given in the table for the single plants of Marquis wheat and Hannchen barley reveal the growth capacity inherent in cereal crop plants. The species of the grass family were closely similar in root diameter being 1.9 feet for Marquis wheat, 2.1 for wild oats and 2.3 for Hannchen barley

whereas the dicotyledenous plants had much larger root diameters varying from 5.4 feet for Hare's Ear Mustard to 17.2 feet for Russian Thistle.

Under competition with other plants of the same species these six species showed quite different results. The species of the grass family were decidedly ahead in total length of root system as well as in total dry matter of the tops. Wild oats and Hannchen barley averaged 841 and 770 feet of roots compared with 82, 117 and 52 for the dicotyledenous weeds. Corresponding differences in the top growth occurred.

The wide difference in the extent of growth of Hannchen barley and Marquis wheat as shown in Table 3 is of much significance as the varieties used are fairly representative of two of the leading crops of Western Canada. A detailed study was made, therefore, of the root systems of the two varieties both with and without competition for several years. The results obtained in 1933 are shown in Table 4.

TABLE 4.—COMPARISON BETWEEN TOP AND UNDERGROUND GROWTH OF SINGLE PLANTS OF *Hannchen Barley* AND *Marquis Wheat* GROWN IN THE CENTRE OF PLOTS TEN FEET SQUARE AND OF PLANTS OF THE SAME CROPS SEEDED IN SIX-INCH DRILL ROWS IN 1933

Characters studied	Hannchen barley		Marquis wheat	
	Single plant	6-inch drills	Single plant	6-inch drills
Top Growth				
Height, inches	25	20	26	19
No. Tillers	127	1	27	1
Seminal Root System				
No. of Seminal Roots	9	6	4	4
Length without branches	378	192	160	123
Greatest penetration, inches	63	30	40	31
Branches of 1st Order				
Longest branch, inches	37	14	32	13
No. per seminal root system	6930	2782	3088	1500
Crown Root System				
No. of Crown Roots	83	4	89	6
Length without branches, inches	1909	5	2314	7
Greatest penetration, inches	63	0	40	0.8
Branches of 1st Order				
Longest branch, inches	32	0	29	0
No. per Crown Root System	23738	0	34710	0
TOTAL Length of Seminal and Crown Roots without Branches,* inches	2287	194	2474	130

*If the lengths of branches of the first and higher orders were included here, the figures for Hannchen barley would be much larger than for Marquis wheat because Hannchen barley far excelled Marquis in the number and length of the branches.

It is of interest first to compare the growth of single plants with that of plants under competition as the season was extremely dry and moisture was a very distinct limiting factor. A single plant of Hannchen barley, growing in the centre of a plot ten feet square, attained the height of 25 inches and produced 127 tillers each bearing a head of a medium size. A similar plant of Marquis wheat attained 26 inches in height and produced 27 well developed tillers. On the other hand, the plants of the same crops grown in 6-inch drill rows free from weeds as a rule produced only one short culm. Similarly, great differences were found in the quantitative

expression of different characters of their root systems. For instance, the seminal roots of single plants of Hannchen barley were numerous and penetrated to a depth of 63 inches below the surface. Those of plants from drill rows were much fewer in number and reached only about 30 inches in depth. The seminal root system without branches of the former measured 378 inches in length, while the corresponding value for plants from the drill rows was only 192 inches. A total of 6,930 side branches of the 1st order was found in the seminal root system of the single plant, but the plants taken from drill rows averaged only 2,782. The longest root branch in the first case measured 37 inches whereas the longest branch in the latter case was 14 inches. Still greater deviations were recorded in the crown root systems in the two cases. Some of these may be enumerated as follows: in the single plant there were 83 crown roots as against 4 in the plants from drill rows; in many instances the former penetrated to a depth of 63 inches, while the latter were mostly only from 1 to 2 inches long and spread horizontally under the surface. The total length of the crown roots without branches in the first case was 1,909 linear inches as against 5 inches in the second case. The corresponding numbers of branches of the 1st order were 23,738 and 0 respectively. Finally, the total length of the seminal and crown roots without branches were 2,287 inches for the single plant, and only 194 inches for plants from the drill rows. The data for Marquis wheat closely resemble those of Hannchen barley.

A comparison of Tables 3 and 4 reveals the fact that Marquis wheat, while much inferior to Hannchen barley in extent of root development in 1932, approached Hannchen fairly closely in 1933. Considering only the the material grown in drill rows in 1933 the main roots of Marquis were 130 feet long compared with 162 feet in 1932. The corresponding figures for Hannchen are 194 and 770. Obviously the dry season of 1933 was much more unfavorable to the barley than to the wheat variety.

COMPARISON BETWEEN ROOT SYSTEMS OF CEREAL PLANTS GROWN IN 6-INCH DRILL ROWS FREE FROM WEEDS AND IN COMPETITION WITH WILD OATS AND WILD MUSTARD

In Table 5 summarized results are given on the root development of Hannchen barley and Marquis wheat, when each is sown at ordinary rates in drill rows free from weeds as compared with when seeded in drill rows with weeds sown between the rows. The presence of weeds in the competition plots furnished the only factor differentiating those plots from the others. The root systems of both cereals and weeds were excavated at 5, 22 and 40 days after emergence and at maturity.

The results demonstrated that competition with weeds cut down the root development of the cereals, particularly in the case of wheat. Marquis suffered far more from competition with wild oats than from competition with wild mustard. At each stage of development up to 40 days after emergence Marquis competing with wild oats had approximately half as long a root system as when grown alone. At maturity Marquis grown alone had a root system 6,070 inches long compared with a length of only 1,948 inches where wild oats competed as against 8,867 inches for the latter. Hannchen barley suffered appreciably from competition with each of the two weeds at the early growth stages (See first and second lines of

TABLE 5.—COMPARATIVE RESULTS ON ROOT DEVELOPMENT OF CROP AND WEED PLANTS GROWN IN COMPETITION. ALL FIGURES ARE IN LINEAR INCHES PER PLANT AVERAGED FROM MATERIAL GROWN IN 1933.

Cereal crop and dates of excavation	Cereal check grown from sowings in drill rows six inches apart	Competition material, the cereal being sown in drill rows six inches apart and the weed being sown in rows between the cereal rows			
		Cereal	Wild Oats	Cereal	Wild Mustard
Hannchen Barley					
5 days after emergence	122	77	13	40	18
22 days after emergence	3355	2989	342	1598	994
40 days after emergence	8374	6575	973	6818	2114
Maturity	10639	9243	947	9110	1408
Marquis Wheat					
5 days after emergence	98	57	35	74	28
22 days after emergence	3031	2155	2063	2219	920
40 days after emergence	4775	2443	2869	3319	2146
Maturity	6070	1948	8867	4078	2683

Table 5). Following 22 days after emergence Hannchen barley, by developing numerous crown roots and increasing rapidly the water absorbing root surface retarded the development of the competing weeds and at maturity had root systems nearly as extensive as those produced free from competition. (See third and fourth lines of the table.)

Considering the fact that barley distributed part of its roots system much closer to the surface than wheat, the Table 5 results are of especial interest. Marquis wheat had a definite advantage over wild oats at five days after emergence, had lost nearly all of this advantage at the 22 day stage and was excelled by the wild oats at the 40 day stage. From then on wild oats gained rapidly until at maturity it had more than four times as long a root system as Marquis. Hannchen barley even at five days after emergence had a very large advantage over wild oats and it steadily increased this predominance thereafter.

The critical period for Marquis wheat in competition with wild oats occurred between 5 and 22 days after emergence. At 22 days after emergence, Marquis had four crown roots, the longest one measuring only a half inch and wild oats had five crown roots each from 2 to 7 inches long. At maturity Marquis competing with wild oats had practically no crown root system whereas wild oats had an extensive one.

It is interesting that the barley affected wild oats much more adversely than it did wild mustard. The root system of wild mustard was approximately half as long (1,408 in.) under competition with Hannchen barley as when competing with Marquis wheat (2,683 in.). On the other hand the root system of wild oats was only one-ninth as long (947 in.) when competing with Hannchen as when competing with Marquis (8,867 in.).

Results obtained in 1934 fully agree with those just presented and discussed. In every case it is obvious that Hannchen barley is more successful in depressing weeds than Marquis wheat. This is due to the fact that Hannchen barley at five days after emergence usually has a larger number of seminal roots and after 22 days after emergence it develops more crown roots than Marquis wheat.

DISCUSSION

Underground Competition

The effects of plant competition have been recognised for thousands of years and it is common knowledge that plants develop poorly when crowded. In the past most of the unfavorable effects resulting from crowding have been attributed to the shading of one plant by another. The present study by demonstrating, as in the case of hare's ear mustard, that competition commences before any shading effects are observable, throws a new light on the causes of competition. It indicates that the roots in some manner are able to rob one another very effectively of plant food substances present in the soil.

The exact way in which the roots of one plant rob those of another is still obscure. It is expected however, that the new technique of root excavation and washing used in the weed research at Saskatoon will lead to further information on the fundamental nature of the underground competition. The critical feature of the washing technique is the use of a very fine water spray to dissolve away the soil particles without damaging the very fine root branches and root hairs. At any stage of washing the exact positions of many of these almost microscopic root structures stand revealed. It is possible therefor to study the position of the fine roots relative to the position of competing roots, the soil formation, the presence of insect and pathogenic pests and various other factors.

Root Development

The study of single plants grown separately without competition is of value in furnishing a clear-cut picture of the mode of penetration and development of the root system of each species. If the developmental tendencies of a single plant growing unhampered by other plants differed fundamentally from the tendencies of plants of the same species grown under competition, there would be little practical value in studying single plants grown alone. However, important growth tendencies, such as the mode and depth of penetration, which characterize a barley plant grown alone are found also to characterize a barley plant grown in an average drill row. The same is true of wheat, oats, wild oats, etc. But the tendency is observed more easily in the root system of a plant grown alone because such a root system is larger and more uniformly developed.

Weed Control Measures

Conclusions based on the experimental results reported in this paper must necessarily be drawn with full regard for the fact that investigations were all made on the chocolate loam soil of the Weed Nursery at Saskatoon. It is quite possible and indeed extremely likely that similar investigations made under widely different soil and climatic conditions would show different results. For example: in the southwestern part of Saskatchewan wheat is a much more successful crop than barley; wild oats are a less serious pest than at Saskatoon; and the Russian Thistle thrives particularly well. In that part of the province the climate is dryer than at Saskatoon and wheat with its deeply penetrating roots has an advantage compared with barley, the main root mass of which keeps nearer the surface. These considerations emphasize the need for conducting on various soil types of Western Canada similar root investigations to those reported here.

SUMMARY

1. Moisture, the predominant limiting factor in plant growth on the open plains of Western Canada, is the most important consideration in weed versus crop competition in that area.

2. The competition commences under the soil surface when the root systems overlap in their search for water and nutrients. The competition immediately manifests itself in the retarded development of the top growth and becomes intensified by top growth competition for light only after shading of one plant by another takes place (See Tables 1 and 3).

3. The yield of Marquis wheat was 40% lower in plots infested with wild mustard than in plots free from weeds. (Table 2).

4. The root systems of single plants grown alone and free from competition from other plants are used as a basis for comparing the effects of different intensities of competition under similar environmental conditions.

5. Plants of barley, wheat and wild oats grown alone in areas ten feet square attained approximately ten times as large a growth of root system and top as plants grown in ordinary six-inch drill rows. Plants of hare's ear mustard, common wild mustard and Russian thistle when grown alone produced from 100 to 1,000 times the growth they had when grown in ordinary six-inch drill rows. (Table 3.)

6. A study was made in the dry year, 1933, of single plants of Hannchen barley and Marquis wheat, each grown in the centre of a ten-foot square, compared with plants grown in six-inch drill rows. Each single plant showed, in addition to a large vigorous seminal root system, a very extensive crown root system. The plants from drill rows were much smaller and had practically no crown root systems. (Table 4.)

7. In a weed versus cereal competition study, Hannchen barley competed much more successfully with wild oats and wild mustard than did Marquis wheat. This is due to the fact that Hannchen at five days after emergence usually has a larger number of seminal roots and 22 days after emergence it develops also more crown roots than Marquis wheat. Marquis wheat in the same study competed fairly successfully with wild mustard, having a total root system 30% longer than the mustard, but was badly depressed by wild oats the latter having more than four times as large a total root length. (Table 5.)

REFERENCES

1. Barnes, S. and E. S. Hopkins. Soil moisture and crop production, Can. Dept. Agric. Bull. 130, N.S. 46 pp. 1930.

2. Clements, F. F., J. E. Weaver and H. C. Hansen. Plant competition. Pub. No. 398, Carnegie Inst. of Washington. 1929.

3. Pavlychenko, T. K. and J. B. Harrington. Competitive efficiency of weeds and cereal crops. Can. Jour. Research, *10* : 77-94. 1934.

4. Weaver, J. E. and Fitzpatrick, T. J. The Prairie. Ecol. Monographs. *4* : 109-295. 1934.

Résumé

Le développement des racines des mauvaises herbes et des plantes cultivées dans les conditions de culture en terre sèche. T. K. Pavlychenko et J. B. Harrington, Université de la Saskatchewan, Saskatoon, Sask.

L'humidité, le facteur qui exerce le plus d'effet sur la végétation des plantes dans les plaines nues de l'Ouest du Canada, est également celui qui joue le plus grand rôle dans la concurrence que les mauvaises herbes font aux récoltes dans cette région. Cette concurrence commence sous la surface du sol, lorsque les systèmes de racines empiètent l'un sur l'autre, en quête d'eau et de principes fertilisants. Elle se manifeste immédiatement par un arrêt dans le développement de la végétation aérienne et s'intensifie par la concurrence de la végétation aérienne pour la lumière lorsque les plantes s'ombragent entre elles. (Voir tableaux 1 et 3). Dans les parcelles infestées de moutarde sauvage le blé Marquis a rendu 40 pour cent de moins que dans les parcelles propres, sans mauvaises herbes. (Tableau 2). Les racines de certaines plantes, cultivées isolément et en l'absence d'autres plantes, servent de base pour comparer l'effet de différentes intensités de concurrence dans des conditions environnantes semblables. Cultivées isolément dans des espaces de dix pieds carrés, des plantes d'orge, de blé et de folle avoine ont produit un système de racines et de tiges environ dix fois plus développé que celui des plantes cultivées en lignes ordinaires, espacées de six pouces. De même, des plantes de vélar d'Orient, de moutarde sauvage ordinaire et de soude de Russie cultivées isolément, ont atteint un développement de 100 à 1000 fois plus grand que celui qu'elles atteignaient dans des lignes ordinaires espacées de six pouces. (Tableau 3). Au cours de l'année de sécheresse de 1933 il a été fait une étude de plantes isolées d'orge Hannchen et de blé Marquis; chaque plante a été cultivée au centre d'un espace de dix pieds carrés et comparée à des plantes cultivées en lignes, espacées de six pouces. Chaque plante séparée portait, outre un grand et vigoureux système de racines séminales, un très grand réseau de racines du collet. Les plantes cultivées en lignes étaient beaucoup plus petites et n'avaient presque pas de racines du collet. (Tableau 4). Dans une enquête sur la concurrence entre les mauvaises herbes et les céréales, l'orge Hannchen a beaucoup mieux lutté contre la folle avoine et la moutarde sauvage que n'a fait le blé Marquis. C'est parce que cinq jours après la levée, la Hannchen a généralement un plus grand nombre de racines séminales et qu'elle développe, 22 jours après la levée, plus de racines du collet que le blé Marquis. Dans la même enquête le blé Marquis a tenu assez bien tête à la moutarde sauvage; son système total de racines était de 30 pour cent plus long que celui de la moutarde, mais il est resté bien inférieur à la folle avoine qui avait une longueur totale de racines quatre fois plus grande. (Tableau 5).

FORAGE CROP PRODUCTION IN A DRY FARMING PROGRAMME[1]

S. E. Clarke[2]

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Forage crop production occupies an important place in any dry farming programme for the western Canadian prairies. Livestock production is one of the most important industries of Western Canada, and therefore the production of feed crops must always occupy an important place in our scheme of agriculture. This fact has been brought home to us during the past few years, during which time there has been an acute shortage of feed over large areas of southern Manitoba, Saskatchewan and Alberta. This shortage of feed has been a serious one, both on the pastures and in the form of hay and feed grain, and during the past winter and spring months it has resulted in rather heavy losses of horses, cattle and sheep. One of the chief problems confronting the stockman today is the production of sufficient feed to carry his livestock through the winter and early spring months in a thrifty condition.

Dry land farming in the prairie provinces is practised in three areas or sets of conditions which might be defined roughly as follows:

(1) Sub-marginal areas;

(2) Marginal areas;

(3) Areas that are particularly adapted for the production of wheat.

The sub-marginal areas are located mostly in southwestern Saskatchewan and southeastern Alberta. Here the amount of available moisture is not sufficient for the profitable production of grain crops. Dotted over these sub-marginal areas are certain districts which might be classed as marginal, as moisture conditions are more favorable and grain growing is practiced to a considerable extent. Even on these more favored portions, however, the farmers tend to go more into livestock production, provided sufficient pasturage is obtainable.

Over these dry areas, the average annual precipitation is approximately 12 inches. Part of this scanty amount is lost by evaporation. Due to excessive winds and high temperatures, the evaporation rate is high, being about 36 inches for the months of April to September inclusive, from an open water surface. Part is lost also by run-off since, in many cases, there is considerable slope and the soil is a fine textured sand or silt that the water does not readily penetrate. Over the greater part of these areas there is little or no sub-soil moisture. A definite lime carbonate layer is found at from a few inches to two feet below the surface. This zone of concentration marks the greatest depth to which the water usually penetrates.

Short season crops, having shallow but extensive root systems, are best suited to such conditions as these. The native grass is the principal crop. Fortunately, a good portion of the precipitation usually falls during April, May and June, and when this is the case, there is a good growth of

[1] Paper presented before the Western Canadian Society of Agronomy at the University of Alberta, Edmonton, June 24–26, 1935.

[2] Assistant Agrostologist.

grass. Grain crops, on the other hand, require a fair amount of moisture throughout July and early August also, and the hot, dry weather often experienced at this time accounts for most of the crop failures.

Since the native grass is the principal crop, ranching is an important industry, and the only farming that the rancher is interested in is that which produces feed for his stock. Wherever possible, irrigation schemes are being developed and here the principal crop is alfalfa. Most stockmen, however, are forced to grow a certain amount of feed under dry land conditions. This is a precarious business, and it is essential that the right varieties be chosen and the proper cultivational methods employed. Crops must be grown primarily for feed; that is, they should be grown on summer-fallow or on other equally well prepared soil. The ground should be prepared during the previous summer or fall, so that the seed can be placed in a firm, moist seed bed early in the spring. If spring plowing is used, it should be packed immediately after being plowed, since loose soil dries out quickly. Nurse crops should not be used unless they are necessary to prevent soil drifting, in which case only a thin seeding should be made and the crop cut early as green feed. Fall rye is a good nurse crop to use for the prevention of soil drifting. Since the native grass provides pasturage, cultivated crops are grown chiefly for hay and grain production. Both fall and spring rye have proven very satisfactory. Spring rye makes the better feed. Under very dry conditions, wheat outyields oats and considerable of it is grown for both hay and grain. When conditions are very unfavorable for cereal crops, there is usually a good growth of Russian thistle, and the grain-thistle mixture makes splendid feed. Russian thistle makes good feed if harvested at the right time and in the proper manner, as this plant has a high protein content and is rich in phosphorous and calcium. The plants should be harvested in the flowering stage. If cut before this they have a lower dry matter content and are very laxative, due to the alkaline salts they contain. If harvested in the seed stage they are not so palatable and are lower in protein and phosphorous. The thistle should be raked immediately after being cut, allowed to dry slightly in the row and then stacked while still somewhat green and moist. Handled in this manner the thistle comes out of the stack in a nice soft condition and makes a palatable and nutritious feed. It should be fed mixed with a fair amount of grass hay, grain hay or straw.

Millet makes a good quality feed for cattle and sheep; it requires warm moist conditions for a short season and therefore can be sown in late May or June. Early strains of corn planted on summer-fallow or on spring plowing, provided there is sufficient moisture to promote germination, yields from two to four tons per acre of nutritious fodder. The seed should be planted early in May and the crop cultivated sufficiently to control weed growth. Sweet clover usually gives fair yields, although it takes two years to produce a crop. Yellow blossom is the best for pasture and the white blossom variety gives the heaviest yields of hay.

When a thin patchy stand of sweet clover is obtained, it is a good practice to seed in about half a bushel of spring rye early in the spring. The rye and clover will be ready to harvest at the same time and this mixture makes splendid feed.

Of the grasses, crested wheat is by far the best for these dry prairie areas. When once established, it does not kill out and it stands close grazing and severe tramping exceptionally well. At the Range Station at Manyberries, crested wheat grass has yielded three-quarters to one ton of hay per acre during the dry cycle of years through which we have passed since 1928. Slender wheat grass kills out badly while brome grass partly kills out and yields very little. A field was sown to these three grasses at the Range Station four years ago and today 90% of the stand is crested wheat grass. A mixture of crested wheat grass and sweet clover has given good results. Alfalfa mixed with crested wheat often does well for a time but, under extreme drought, the alfalfa kills out badly. These crops grown in rows spaced from 2 to 3 feet apart and cultivated once or twice each summer, usually outyield the close drilled crops.

In the marginal areas also, forage crop production holds an important place in our agricultural programme. Here precipitation is somewhat greater, being nearly 16 inches at Lethbridge, and about the same at Swift Current. The evaporation rate is slightly lower and the per cent run off is less than in the sub-marginal areas. While wheat production has been greatly developed, farming is ruled by Nature in a very capricious mood, and crop failures are frequent. In many districts mixed farming is practiced, and livestock holds a very important place in the farming operations. As one farmer puts it: "The grain crop may prove a failure but we can nearly always gather together considerable feed, when our wheat is not worth harvesting as a grain crop there is lots of thistle among it and this gives us a good crop of feed."

Many of the farmers in these areas are handicapped by a lack of pasturage. The farmer-rancher idea needs to be further developed. Agriculture would be on a much more permanent basis if many of the farmers controlled a greater acreage and cultivated the better portions and used the balance as pasture. Community pastures also serve a useful purpose in such districts.

As this transitional marginal area changes on the north and on the east to above-marginal, or wheat-growing areas, the number of livestock kept and the acreage devoted to forage crops decreases. Precipitation increases to approximately 18 inches at Indian Head, and to 20 inches at Winnipeg Loss by evaporation and run-off is still further decreased. While during the past few years these areas have suffered from drought and soil drifting, and while a recurrence of such conditions may necessitate a change in farm practices, soil and climatic conditions are, on the whole, particularly adapted for the production of wheat and other small grains. Here practically all of the land is under cultivation, with little left as native pasture. In fact it is not profitable to leave this high-priced, high-producing land to the native grasses. Arable land produces more hay or pasturage when brought under cultivation. However, a limited number of livestock should be kept. The farmer should provide his own eggs, meat and milk. A few horses are needed, and near the towns and cities, dairy herds must be maintained; therefore, a certain acreage must be devoted to the production of feed crops.

On the drier portions of the marginal areas, the same varieties of feed crops should be grown and the same methods of cultivation practiced as on

the sub-marginal lands. Under more favorable conditions, as found especially in the wheat growing sections, feed crops are grown largely as a part of various crop rotations. Inter-tilled crops, such as corn, are grown as cleaning crops or summer-fallow substitutes. The growing of feed crops such as grasses, alfalfa, etc., also has an important place in the control of weeds and in the prevention of soil drifting. Forage crops are not grown primarily for feed production to the same extent as on the drier areas, but serve other purposes also in the farm programme.

For pasture purposes, brome grass, meadow fescue, creeping red fescue, slender wheat grass, sweet clover, sown separately or in mixtures, give good results. At Brandon a mixture of brome and alfalfa has done exceptionally well, while at Lacombe a mixture of timothy, slender wheat grass and alfalfa gives splendid pasturage. It has been found that the grasses have a higher protein value when grown with the legumes. The same varieties are suitable for hay production. Slender wheat and alfalfa as a mixture does well at Indian Head; brome and sweet clover thrive at Rosthern; brome mixed with alfalfa or sweet clover yields well at Brandon; while slender wheat grass does particularly well in the Scott district. Crested wheat grass does not do as well compared with the brome and slender wheat as on the drier areas. Arable farm pastures should be brought under cultivation and seeded down to a grass-legume mixture. A small acreage at least should be grown also for hay production. No attempt should be made to fit these grass crops into a short rotation. They should be left for 8 or 10 years or more, or as long as they continue to be sufficiently productive. They fit well into a long rotation and have an important place in the control of certain insects, weeds and soil drifting. In these areas annual crops hold an important place both for pasture purposes and for hay production. Oats give high yields of palatable and nutritious fodder and sown thinly on summer-fallow they provide good pasturage and at the same time act as a cover crop in the control of soil drifting. Barley, wheat and rye are other crops that can be used for the same purposes. Millets and Sudan grass are grown to some extent. Corn is becoming an important feed crop, the acreage during 1934 being about three times that of 1933. Early strains produce fair yields of grain while later sorts are grown for fodder and for ensilage. In certain sections corn is being grown largely as a summer-fallow substitute.

In conclusion, the production of forage crops occupies an important place in a dry farming programme, first as providing feed for livestock, and second, in the control of weeds, the prevention of soil drifting and in the improvement of soil conditions for the production of other crops.

RELATION BETWEEN RATE OF SEEDING AND YIELD OF CEREAL CROPS IN COMPETITION WITH WEEDS[1]

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INTRODUCTION

In 1930 and 1931, in the course of investigations with chemical sprays to control annual weeds in grain fields, the writer observed that fields sown at a heavier than normal rate had less weeds before treatment. This led to the belief that there might be some weakness in recommendations regarding the rate at which cereal crops should be sown, and it was decided to undertake a thorough investigation of the question of rates of seeding in weedy fields. Such experiments are now being carried out by the Saskatchewan Department of Agriculture for the fourth successive year. This year, plots have been laid out at Melfort, Grenfell, Assiniboia, and a network of simple strip tests throughout the province.

WHY RATES OF SEEDING EXPERIMENTS SHOULD BE RESUMED

A great number of people have thought that the question of rate of seeding is one which had been settled long ago. Fairly extensive trials to determine the rate at which crops should be sown were made in the early days, and those were probably among the first experiments done as new experimental stations were opened. It was found then almost unanimously that light seeding was best; the yield difference between light and heavy seeding was usually not significant, but light seeded crops stooled better, had longer heads, stronger straw, and heavier seeding did not give sufficient increase in yield to pay for the extra seed. When the weeds came we looked for control by means of better tillage, shorter rotations and chemical treatment; when our crops froze or the grain germinated in stooks because the crop was sown late on account of weeds, we looked for earlier varieties. Conditions have changed in many respects on our farms during the last twenty-five years and most farmers know the difference between old land and new breaking on old land. Crops do not have the same vigor—they stool less. We weaken the viability of our seed wheat with formalin treatment; we have root rots, wireworms, cutworms, to thin out the stand; and weeds of some kind are almost always present to take advantage of any weakness shown by the crop and especially to grow in the spaces which a mechanical imperfection of our grain drills has left on the drill rows.

In the Park area of Saskatchewan, little emphasis has been laid on the point that the grain kernels being usually larger than in the south, less seeds are sown per unit area than in the south, when the contrary should occur.

EFFECT OF HEAVIER THAN USUAL SEEDING ON CLEAN LAND

The main argument against heavy seeding is that it provides too many plants per unit area for the available moisture in the soil. It is usually claimed that in dry years the light seeded crop suffers less from

[1] Paper presented before the Western Canadian Society of Agronomy at the University of Alberta, Edmonton, June 24–26, 1935.

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drought while in wet years it adjusts itself to the more favorable conditions of moisture by stooling heavier. This is true. Heavier than normal seeding on clean land reduces the development of cereal plants, straw and heads are shorter, and there are fewer tillers. On the other hand the yield of grain is not reduced because of the added number of plants sown (see Table 1).

TABLE 1.—EFFECT OF HEAVIER THAN NORMAL SEEDING ON THE DEVELOPMENT OF MARQUIS WHEAT SOWN APRIL 28, 1933, ENGLEFELD, SASK. CROP CLEAN.

	Rate of seeding		Difference	
	1¼ bu. per A.	1¾ bu. per A.	In units	In %
Yield per acre—Bus.	19.8	20.2	+0.4	+2.0
Length of heads—Cm.	5.3	4.8	−0.5	−9.3
Wgt. 1,000 kernels Gr.	32.0	31.3	−0.7	−2.2
Tillers per 100 plants	111	104	−0.07	−6.3

Heavy seeding on clean land advances by a few days the maturity of cereal crops and this, in northern districts especially, is no small advantage. Heavier seeding also helps to keep weed plants from developing too fast and so retards, if not prevents, the general infestation of the fields. For these reasons alone, farmers whose land is still relatively free from weeds might well sow heavier than in the past.

EFFECT OF HEAVIER SEEDING ON WEEDY LAND

Much has been written about the losses due to weeds; they increase the cost of tillage, they reduce the commercial value of grain, they increase the cost of transportation, and so on; but, above all, they reduce the yield of crops, and the extent to which this loss occurs is little understood. Experiments carried over a period of years have shown that even a very light weed infestation lowers the yield of grain crops, and that the more weed plants there are per unit area, the greater the loss is.

The damage done by weeds in growing crops is not spectacular, except in extreme cases, when they crowd out the young crop and thin out the stand. The chief loss in most cases is due to a reduction in the size of heads or panicles; second in importance is the decrease in tillering; and third is the reduction in weight of kernels (see Table 2).

TABLE 2.—EFFECT OF ANNUAL WEEDS ON THE DEVELOPMENT OF MARQUIS WHEAT. AVERAGE OF 8 SAMPLES IN EACH CASE. ENGLEFELD, SASK., 1933. RATE OF SEEDING, ONE QUARTER BUSHEL PER ACRE

	Crop clean	Crop weedy	Difference	
			In units	In %
Length of heads (Cm.)	5.3	4.4	− 0.9	−17.3
Tillers per 100 plants	111	100	−11	−10.0
Wgt. per 1000 kernels	32.0	31	− 1.0	− 3.1
Yield per acre	19.8	12.9	− 6.9	−34.8

NOTE: Measurements of length and counts on stooling are the average of 25 plants for each sample, or 200 plants in each case.

The data gathered in the course of our rate of seeding experiments show that the loss of yield reported in Table 2 is a fair average of the loss sustained by farmers over a period of years, if their land is severely infested with weeds.

Of all weeds growing in grain crops, annuals are by far the worst, because they not only lower the yield but mature early, and produce a large amount of seeds, which shatter in the field before harvest. Shallow tillage, short rotations, clean summer-fallowing, and the seeding of clean seed are good control measures, but insufficient and little progress in weed control will be made until we first check the development of weeds in the growing crops. Spraying and harrowing have been advocated for this purpose, but both methods are effective only at certain stages of plant growth and only with some weeds. Control by smothering appears as the only practical solution and the method which we recommend for general use in the Park area of Saskatchewan, where it has proven so valuable, *consists in seeding cereals early, heavier, shallowly, and with commercial fertilizers.*

Root studies at the Weed Nursery, University of Saskatchewan, show that cereals at emergence have a more developed root system than any weed of the same age. We further know that the seeds of cereals germinate uniformly at a lower temperature than those of most weeds. On the other hand, experience has shown that cereals sown lightly cannot successfully compete with weeds and that early sown crops are slow to grow, unless commercial fertilizers are used.

We, therefore, recommend early seeding of the crop to secure its germination ahead of weeds, shallow seeding to have quick emergence, and fertilizing to provide a rapid development of the crop. We recommend heavier seeding to accelerate the formation of a dense mat of cereal roots, so as to smother weeds more effectively, to avoid misses in the rows and to quicken the shading of the spaces between the rows.

If weeds do germinate at all in the spring, a cereal crop sown heavily does not suffer for want of moisture, any more than a crop sown lightly, because the additional number of plants sown utilize moisture which would otherwise go to the weeds.

Heavy seeding on weedy land reduces the size of crop plants some, but not as much as on clean land. The yield of grain harvested, on the other hand, is usually increased by a few bushels per acre (see Table 3).

TABLE 3.—EFFECT OF HEAVIER SEEDING ON THE DEVELOPMENT OF MARQUIS WHEAT SOWN APRIL 28, 1933. CROP WEEDY. ENGLEFELD, SASK.

	Rate of Seeding		Difference	
	$1\frac{1}{4}$ + bu per A.	$1\frac{3}{4}$ + bu. per A.	In units	In %
Length of heads (Cm.)	4.36	4.21	−0.15	− 3.5
Tillers per 100 plants	100.	100.	—	—
Weight per 1000 kernels (gms.)	31.0	30.2	−0.8	− 2.6
Yield of wheat per acre (bus.)	12.9	15.0	+2.1	+16.4

Our experiments of rates of seeding on weedy land are far from concluded. We have to date shown that annual weeds can be economically controlled in cereal crops in northeastern districts of Saskatchewan, where we suggest the following rates:

Wheat	$1\frac{3}{4}$ to $2\frac{1}{4}$ bus. per acre
Barley	2 to $2\frac{1}{2}$ bus. per acre
Oats	$2\frac{1}{2}$ to 3 bus. per acre

The exact rate within those limits will depend on the variety sown, the condition of the land at seeding, the size of grain kernels, the degree of weed infestation of fields, etc.

Too little experimental evidence has been secured to date in the rest of the province to recommend a change in the rate of seeding, although there are strong indications that some action along that line may have to be taken sooner or later.

ANNUAL MEETING OF THE WESTERN CANADIAN SOCIETY OF AGRONOMY

The Annual Convention of the Western Canadian Society of Agronomy was held, in conjunction with the Canadian Society of Technical Agriculturists' Annual Convention, at the University of Alberta, Edmonton, Alberta, during the week beginning June 24th, 1935.

A splendid program was prepared by the 1934–35 officers, who were: Dr. O. S. Aamodt, Agronomy Department, University of Alberta, President; Dr. J. B. Harrington, Agronomy Department, University of Saskatchewan, Vice-President; G. E. DeLong, Dominion Experimental Farm, Lacombe, Alberta, Secretary; D. A. Brown, Dominion Experimental Farm, Brandon, Man., and Dr. J. R. Fryer, Agronomy Department, University of Alberta, Directors; Dr. J. D. Newton, Soils Department, University of Alberta, Curator. In the absence of Dr. O. S. Aamodt, who left earlier in the year to accept the position of Chief of the Agronomy Department, University of Wisconsin, Madison, Wisconsin, Dr. J. B. Harrington presided.

The following officers were elected for 1935–36: President—Prof. J. Ellis, Soils Department, University of Manitoba, Winnipeg, Man.; Vice-President—G. E. DeLong, Dominion Experimental Farm, Lacombe, Alta.; Secretary—T. M. Stevenson, Dominion Forage Crops Lab., Saskatoon, Sask.; Directors— S. H. Vigor, Field Crops Commissioner, Regina, Sask.; K. W. Neatby, Prof. of Field Husbandry, University of Alberta, Edmonton, Alta.; Curator—Dr. J. D. Newton, Soils Department, University of Alberta, Edmonton, Alta.